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Journal of the Radio Amateur Space Program

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Editorial Office: P.O. Box 575,
Wharton, NJ 07885

AMSAT: P.O. Box 27, Wash., DC 20044.
Telephone: 301 589-6062
Telex: 248-566

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Our Cover: The satellite station at OE1VKW includes an impressive array of antennas. Shown are a 9-element crossed Yagi for 145 MHz, four 21-element Yagis for 435 MHz, and an unusual 25-turn helicone antenna for 1.269 GHz.

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Ellipsis...

An Editorial by Harold Winard, KB2M

The View From The Turning Point

The present is often not the best place to view the future from but, like it or not, it's the only place we have. Yet despite the handicap and the uncertainties that result, prognosticators have long had a very enthusiastic audience for their seemingly magical glimpses into the dark future.

Why have people been fascinated by every seer from Nostradamus to Jean Dixon and probably quite a bit before that? Probably a fear of the unknown and a desire to assure themselves of the assumed certainty of their future existence.

But not all things in the future are so vague or cloaked with mystery that the less clairvoyant among us can't uncover their meaning. As any academician will tell you, the past is a true guide to the future and a surprisingly accurate one. There is little indeed that has happened to humanity in the last several million years that is not going to happen, in one form or another, in the future. With the exception of some atomic particles that may have been truly synthesized by man, there is probably nothing new under our sun.

Armed with an outline of the past, those of us in the present daring enough to venture forth can develop some very plausible and probably accurate assessments on our future fate.

Undoubtedly now is the best time for all of us in the amateur radio community to make a considered judgement about the future of amateur satellite activity. The first OSCAR went into orbit some 23 years ago. By current reckoning in the electronics and space science world that's a very long time indeed, but one filled with a variety of valuable experiences from which we can do some surveying into the future.

To start with, let's look backwards to the early days of the amateur satellite program when a handful of skilled engineers fabricated a tiny package in their own homes and offered it is as a replacement for the ballast that would have been fitted to a U.S. launch vehicle. OSCAR-1 answered Don Stoner's challenge, but only partially for it would take others, in years to come, to build repeaters in space that demonstrated the perseverance of amateurs in general and the skill of a widening group of technicians, engineers, scientists, and researchers.

Succeeding OSCAR satellites did more than just announce their presence. From a single repeater channel and limited life spans, the amateur community evolved sophisticated rf packages that provided predictable communications performance, albeit for just 15 to 20 minutes at a time. Soon the weeks and months that earlier satellites spent in useful life became years, in some cases years beyond design forecasts.

Last year the scientists, technicians, engineers, researchers, planners, writers, and administrators held their collective breaths as the flight control officer at the European Space Agency's Kourou launch facility recounted the flight events as the Ariane rocket pierced through the atmosphere and hurled Phase IIIB into a transfer orbit. Yes . . . OSCAR-10 had made it and the world of amateur radio had its first practical communications satellite.

The now widening circle of experts didn't let the grass grow under their feet nor did they rest on the laurels of their past achievements. In the past year UoSAT-OSCAR-11 sprung to life high over the earth carrying a sophisticated scientific payload and a future-oriented digital communications experiment. Even in the agony of its premature silence, Hams marshalled the forces of accomplished amateur radio operators around the world to mount an intensive campaign to listen for the minuscule signals emanating from the crippled satellite. Yet another group of experts had been added to the growing family of upward looking communicators.

OSCAR-11 is safe now, working by virtue of the persistence of the ground crew at the University of Surrey, the dedicated Hams within the California-based SRI International research facility, and the clever circuit design that allowed substitution of one controller for another to restore command functions within the bird.

That brings us to the present and a very important time it is. Would we to ride through the time machine to the next century, I am sure that 1984-1985 would be seen as the turning point in the amateur space program. The handful of pioneers tinkering in their basements has grown to an accomplished force of many with diversified fields of expertise. The simple packages are now very complex combinations of digital and analog circuitry. Even the flight hardware, such as the propulsion systems and their controllers, are many orders of magnitude more elaborate than anything hams have flown and controlled before. And it will become even more complex. So complex, in fact, that homebrewing will be out of the ques-

Continued on page 8

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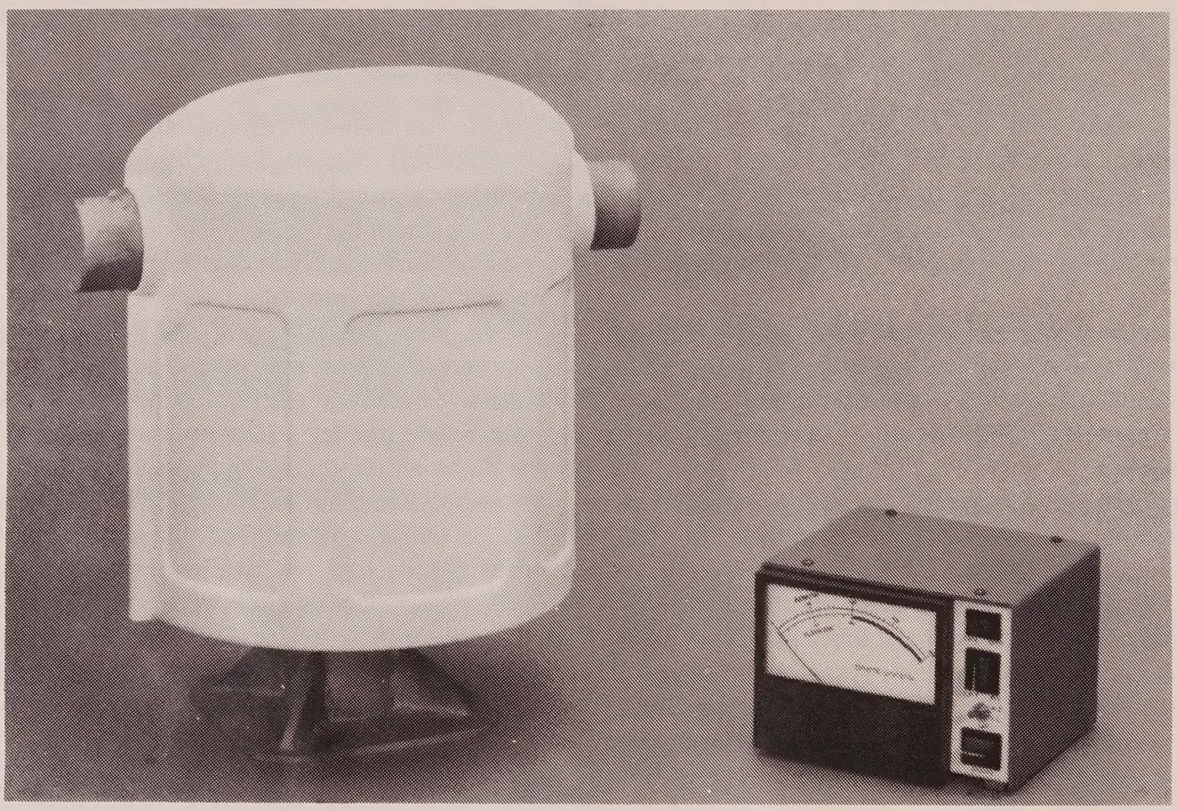

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Using Water as a Primary Method of Propulsion for Spacecraft Modifying Standard STS Orbits

By Jan A. King, W3GEY

The Space Shuttle has modified the method by which space-bound payloads enter orbit for the forseeable future. The STS offers the promise of lower payload cost and the ability to carry large payloads into orbit to mention but a few of its primary objectives. For very low cost payloads such as those pioneered by the radio amatuer community (the OSCAR series), however, the Space Shuttle poses a number of severe engineering constraints which have impeded exploitation of this valuable resource. Not unlike most free flying satellites, the communications satellites launched by radio amateurs and used in the Amateur Satellite Service are intended for long life. In addition, to meet mission objectives for the communications service to be provided, either a geostationary transfer orbit or a sun synchronous polar orbit must be attained by the spacecraft. Unfortunately, neither of these objectives can be met by the standard Space Shuttle mission.

STS orbits, typically 296 km in altitude and inclined in the range of from 25 to 57 degrees, are unstable. A small spacecraft, with a low surface area to mass ratio, will decay from such an orbit in a matter of months. This class of orbits, with few exceptions, is also unsuitable for communications experiments of interest to the Amateur Satellite Service. It is therefore necessary for Amateur Satellites and other free flying spacecraft to carry a propulsion capability to attain stable orbits much higher than that afforded by the Space Shuttle.

Having accepted the burden of a propulsion system as an added spacecraft complexity, yet another problem arises. Classical propulsion systems employed by satellites are justly characterized as hazardous devices. With humans on-board Shuttle, safety considerations are necessarily more stringent when launching a spacecraft. The added complexities and paperwork required for the inclusion of hazardous devices on board Shuttle-launched satellites drives up the cost of these programs and may make such payloads totally impractical or viable only if launched by alternative methods. This problem is exacerbated by the fact that most orbit alternatives can be reached from Shuttle orbits only by multiple acceleration maneuvers. This requires multiple solid rocket engines or a restartable engine on-board the satellite, further multiplying the safety hazard problem.

A solution is sought to the "Shuttle Dilemma." The Shuttle Dilemma may be defined as follows:

1. A Shuttle payload is always two burns away from the desired orbital elements when separated from the cargo bay.
2. The cost of NASA safety approval for a propulsion device used aboard Shuttle by a low-cost user is approximately a factor of three higher than the entire cost of the payload itself.
3. As a rule of thumb, the mass of the paperwork necessary for NASA approval of a hazardous device for a Shuttle flight is greater than or equal to the mass of the payload.

While cast in a facetious vein, these factors must be dealt with squarely by would-be Shuttle low-cost payload designers.

1. The propellant used should not be a chemical, pressure or explosive hazard as defined by NASA or the USAF (ref. AFETRM-127-1).
2. The loading of propellant into the spacecraft should not constitute a hazardous activity. No special safety equipment should be required.
3. No portion of the propulsion system should contain hazardous devices of any kind. Certain exceptions to this rule might be taken to include category B electro-explosive devices such as pyrotechnically operated valves.
4. No portion of the propulsion system should be pressurized or become pressurized even remotely while the satellite is on the ground, during powered flight or during astronaut activities in orbit, including those conducted to separate the satellite from the Shuttle.
5. No portion of the propulsion system should be susceptible to damage due to the environment of the Cargo Bay during powered flight or in orbit prior to or during separation of the satellite.

The Radio Amateur Satellite Corporation (AMSAT), having had practical experience with both liquid and solid propulsion systems on board low cost satellites believes that these requirements will prove immutable for low-cost payloads flown by the Space Transportation System. Two methods have been considered by AMSAT that appear to meet the above five conditions and produce satisfactory performance for space applications. Both involve using water as a fuel and both have been considered by other groups from time to time as methods of space propulsion.

Propulsion via Water Electrolysis

The propulsion of a space vehicle via hydrogen/oxygen fuel produced from electrolysis of water is far from a novel idea. Hughes Aircraft Company, Space Systems Division documented the results of an internal research and development (IR&D) project which developed a working model of a water electrolysis rocket during the first half of 1964 (1,2,3,4). Using this technique a single pressure vessel acts as storage for the water and electrolyte, as an electrolysis chamber and finally as a pressure bottle for the combined electrolyzed gases. The premixed gas may be fed via a single line into the injection chamber of a small rocket engine or thruster. In their final report on this technology Hughes stated:

"The Water Electrolysis Rocket has been explored in sufficient depth to verify the feasibility of the concept. Furthermore, it has been determined that this system offers significant advantages over other presently available reaction control systems. Among these advantages are:

1. Higher specific impulse
2. Lower system weight
3. Lower power requirements
4. Extended life in space
5. Improved system reliability
6. System simplicity"

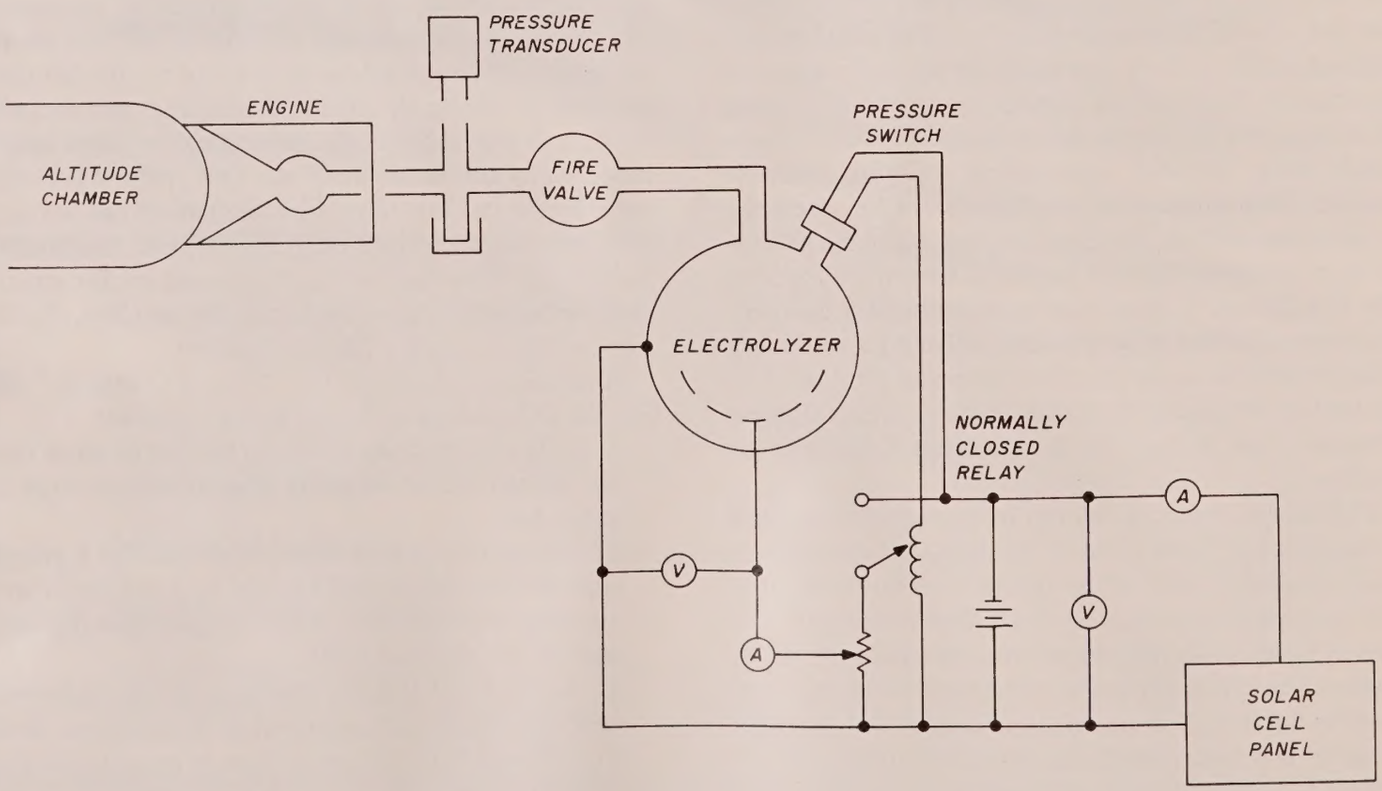

Fig. 1 — Water Electrolysis Rocket System Schematic

It is interesting to note that at the time of the writing, Hughes did not consider the safety advantages of the system which are of prime interest to AMSAT. The specific impulse of a small electrolysis motor of the type required for a low cost satellite mission is between 330 and 360 sec. This is considerably better than either an equivalent solid or bipropellant liquid motor system (270 and 305 sec. respectively). Preliminary investigations by AMSAT suggest that the power required to electrolyze one kilogram of water is approximately 5,000 WH. This may be related to delta-V for a specific satellite case as shown in Table 1. A minimum system schematic is shown in Fig. 1.

Why Hughes did not continue to develop this technology to the point of commercial introduction is unknown. Clearly, however, monopropellant hydrazine systems replaced other methods for reaction control starting about the same time as the Hughes research on water electrolysis motors. Since this work was done there have been dramatic improvements in both electrolysis electrode and thruster technologies. AMSAT has also conducted preliminary studies on an advanced method of drying the hydrogen and oxygen gas which should lead to improved thruster performance. This was one problem reported by the Hughes research team.

Propulsion By Steam Expulsion

A second method of exploiting water as a safe propellant is by means of a small steam engine integral to the thruster in a water fed propulsion system. Water is allowed to superheat in a small chamber adjacent to an expansion nozzle. Thrust is produced by the acceleration of water molecules as they exit the nozzle. The specific impulse of this technique is far poorer than the electrolysis method (107 sec.). However, the system complexity is very low indeed and the energy required to liberate a kilogram of water into steam is only 750 WH, considerably less than with electrolysis. The specific impulse for a motor of this type can be shown to be governed by the equation:

$$I_{sp} = \sqrt{\frac{2C \cdot K \cdot T_b \left(1 - \frac{Pexit}{Pchamb}\right) \cdot C - \frac{1}{c}}{(c-1)\, n \cdot m}}$$

where:
C = Heat capacity of propellant (water = 1.3)
K = Boltzman Constant = 1.38E-23 J/K
T_b = Gas Temperature = (approx.) 400K
n = molecular weight of propellant (water = 18)
m = mass of a hydrogen atom = 1.66E-27 Kg
Pexit = Nozzle exit plane pressure (assumed = 0.01 Bar)
Pchamb. = Thruster chamber pressure (assumed = 5.0 Bar)

As can be seen, the specific impulse depends inversely on the molecular weight of the fuel used, taken to the half power. This favors the use of low molecular weight fuels. Water is nearly optimum for an engine of this type particularly when the other physical properties of this fluid are taken into consideration in a practical system.

While a system using steam as a propulsion technique is far from optimum with respect to Isp, on balance it is simple enough to be included on even GAS can missions and can solve significant propulsion problems for small spacecraft. Fig. 1 reviews the performance of this system for a variety of missions of interest to AMSAT and gives a comparison to the electrolysis method.

Orbit Height	ΔV Required	Water Mass Required Steam Expulsion	Water Mass Required Electrolysis
1500 km	612 m/sec	38.5 kg	9 kg
850 km	300 m/sec	16.5 kg	4.4 kg
550 km	141 m/sec	7.2 kg	2.4 kg

$\frac{\Delta V}{kg}$ = 58.75 m/sec-kg

Given:
- S/C MASS = 50 kg (Dry)
- STS ORBIT = 296 Km Circ.
  = Base Orbit
- Hohman Transfers/Burst Mode

Table 1 — Water Propulsion System Performance

Orbit Correction Technique Using Water Propulsion Methods

A salient characteristic of both propulsion techniques reviewed is that they take electrical energy from the solar arrays of the spacecraft and convery it into potential energy (either in the form of stored gas to be burned or in the form of stored electrical energy). Thrust is best produced in a burst mode rather than with a continuous firing. This is a typical operating mode for a reaction control system (RCS) but is somewhat unusual for an orbit transfer maneuver. In effect, time is traded against the burn duration (power production rate of the satellite) so that a reasonable compromise for the total duration of the propulsion phase of the mission is reached. An important consideration for such a mode of operation is that the total delta-V achieved during the maneuver must be greater than the decelleration due to drag in the Shuttle base orbit. The orbit transfer strategy for circular orbits with a spinning spacecraft is shown in Fig. 2. Two small thrusters at either end of the satellite are employed. Firings always occur at the line of apsides. Alternate thrusters are used so that a first firing occurs at perigee thus raising apogee and a subsequent firing occurs at apogee raising perigee. Mini-Hohman transfer maneuvers are repeated until the desired circular altitude is reached. Elliptical orbits can be achieved with a single thruster fired at consecutive perigees thus continuously raising

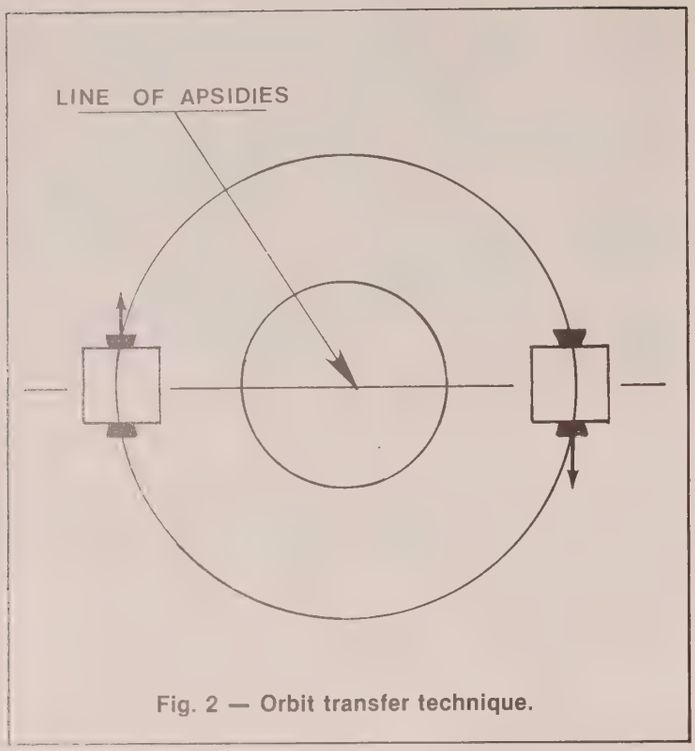

Fig. 2 — Orbit transfer technique.

apogee. Inclination changes with this technique are also possible and are most efficiently applied when apogee also coincides with the ascending node of the orbit.

Summary

The techniques reviewed have been considered in the past by space research projects and by commercial spacecraft manufacturers. While these propulsion technologies have never been reduced to commercial practice, sufficient study has been done to verify their applicability to space missions. If the STS is going to fulfill its mission as a launcher for all space interests then some acceptable methods of propulsion must be found for smaller payloads. These methods must take into account the low-cost nature of such projects and the very stringent safety constraints imposed by NASA on all STS users. In view of this, AMSAT believes that water propulsion technologies should be revisited because they have the potential of solving the "Shuttle Dilemma" for a class of users that can bring significant benefit to the space program as a whole.

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tion and high-performance test systems and vacuum chambers will become the tools with which all future OSCAR satellites will be built.

A turning point, I said? Yes indeed. We can say goodbye to the pioneering days when launches were free, equipment relatively inexpensive, and home workshop test equipment adequate. The new generation of OSCAR satellites will demand resources, technical and otherwise, that will stretch the amateur community beyond its ability to provide. Thus the fate of the amateur satellite program rests increasingly with a wide range of previously insignificant factors. Governments, universities, private industry, foundations, and other space-related organizations. Even if hams shed their penurious image and dig exceedingly deep into their pockets, the money so garnered will still be insufficient to sustain an advanced amateur satellite program.

The economics of amateur satellite endeavors is not the only thing that is changing. The cost of the satellites has gone up but not totally because of inflation. Much of the money simply buys a better and more versatile satellite. Should we hold the reins on technical improvements to keep the costs down? That's one answer and, in some aspects, a defensible one. But overall, maintaining the status quo is not what amateur radio is supposed to be about.

When the first OSCAR was launched, we set ourselves on a course that is now a substantial definition of what technical achievement is all about. We are not building and launching satellites simply because space is there; we have ventured forth above the atmosphere because that's where a major portion of our efforts must be directed to achieve reliable, long-range communications.

The ultimate decision on just what will follow the Phase IIIC mission is still a few years off. But the response of the amateur community to the feelers being put out now by the satellite builders will play an important part in deciding what, if anything, is launched into space after 1986. It can remain low-orbit or Molniya-type satellites or it can be as mind-boggling as a constellation of geosynchronous satellites ringing the world with a practical and more reliable alternative to the ionosphere.

Your opinions are important and will have their effect in determining which direction the amateur radio community heads in the next several years. If you would like to air your feelings to others, let me know. If enough comments are received, they will be printed in the pages of a future issue for all to see and discuss. Drop me a note at the editorial address shown on the masthead of this issue and I'll do my best to see that others can share your thoughts and suggestions. Help AMSAT take its bearings at this crucial time in its life.

ORBITALKER:

An OSCAR Information Center

By Stewart Beal*, VE3MWM

Have you ever thought about keeping local satellite enthusiasts up-to-date on orbital elements? Here's one way to do it that proves that talk can indeed be cheap, and helpful.

Not long after AMSAT-OSCAR 10 was launched, AMSAT exhorted weekly net listeners to spread the word about amateur radio's latest and most powerful communications tool. A suggestion from Vern Riportella, WA2LQQ, got me thinking about how best to disseminate orbital information — such as azimuth, elevation, and visibility times — via local vhf and uhf repeaters. My thinking led to Orbitalker, a self-contained voice information system that actually speaks orbital predications over a local repeater in response to DTMF commands.

My project started with an investigation of a device, called the Universal Processing Board, which was developed by a fellow ham. That board is a Z80-based affair with up to 32 kbytes of ROM, 4 kbytes of static RAM, a 20-key hex keypad, a 16-character alphanumeric LED display, and sockets for various types of peripheral chips. Those ICs could support parallel and serial communications plus a counter-timer function. One large and several small prototyping areas on the board permit other devices to be added. The first addition to the board that I acquired was an MSM5832 real-time clock/calendar.

My board was from an early production run, and after hand wiring some corrections to it (early runs are like that — a few errors!), I had an operating processor board. First thoughts turned towards interfacing it to an analog-to-digital converter and a couple of relays to use it for control of my antennas. In that configuration I could have downloaded the time and azimuth/elevation information from my S-100-bus computer and let a simple program in the processor board do the interpolation and control.

After thinking about the idea for a while I realized that the board had sufficient room in its ROM for a modification of the W3IWI orbital prediction program. With that thought in mind, the Orbitalker concept gelled.

I started off with C language for the application because experience at work had taught me that C code was easier to write and debug. Also it was usually correct in structure from the beginning and often produced smaller object-time modules than other languages. The Aztec C-II compiler from Manx Software Systems was chosen since it was the most reasonably priced package that offered full floating-point support plus ROMable code. In addition, source code of the complete library was provided. That enabled me to make modifications and deletions to produce modules as small as possible.

I quickly learned that orbital data could not be calculated for the user on demand — the program is simply too slow. However, the routines were redesigned so as to maintain, at all times, 10 events for each satellite that was being tracked. An event, in this case, was a single observation of a satellite's state. The data in each event was the time, azimuth, elevation, range, Doppler shift,

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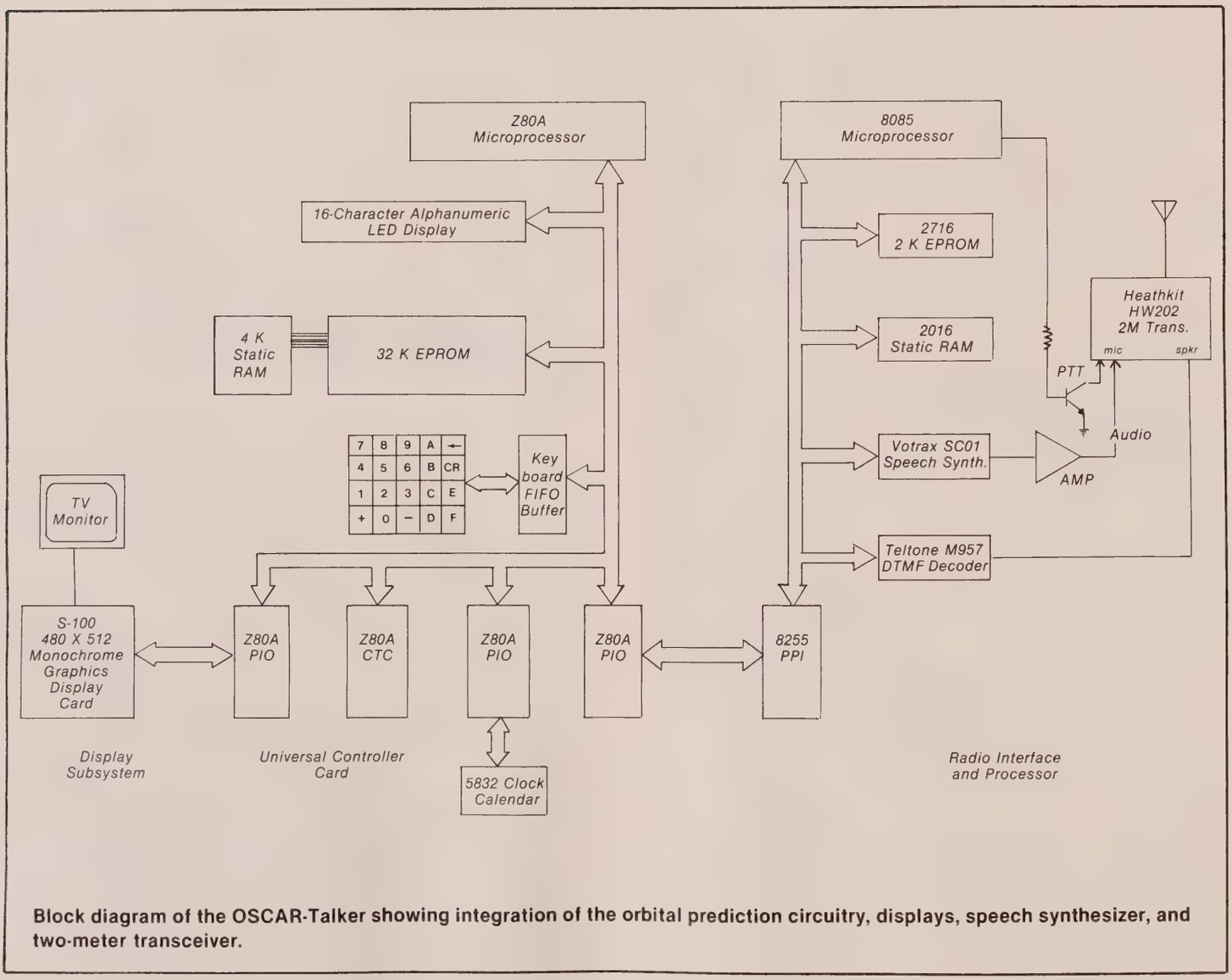
and phase. The sub-satellite point and height above the earth are also kept.

The events were the next 10 visible points on the satellite's orbit, at one-minute intervals. Therefore the first event would be the current opportunity to use the satellite, or the first event in a future pass if the satellite was not currently visible.

If the satellite was due to set before all 10 elements were filled, the next visible orbit would be calculated until 10 acquisition times became available for the six usable satellites — RS 5 through 8, UoSAT 9, and OSCAR 10. The program would then continuously monitor the real-time clock and calculate new events for addition to the end of the lists. That was required since they would be removed from the beginning by the passage of time. The program could be interrupted at any time to insert new orbital elements, to change the observer's location (including height or horizon), or to change the setting of the real-time clock.

The means of activating the system and receiving information from it did not take long to decide. A DTMF decoder and a Votrax SC-01 speech synthesizer chip were to be used for the input and output respectively. Since the system would be calculating satellite orbital elements and it would be near my operating position, alphanumeric and graphics displays were included for my use. The display consisted of a bit-mapped monochrome graphics processor with 40 lines of 85 characters plus graphics capabilities. The processor in that card was also a Z80. The firmware for it permitted downloading of code to it for fast internal operations.

Connection and operation of the processor board and graphics card were easy and implementation of the data production program — the one that continuously calculates the events — was quick. However, the one aspect of the project that made me uneasy was the tone-speech interface. I selected Steve Ciarcia's "Sweet Talker" design from the September 1981 issue of *Byte*



Block diagram of the OSCAR-Talker showing integration of the orbital prediction circuitry, displays, speech synthesizer, and two-meter transceiver.

magazine for the speech function plus a single-chip DTMF decoder, the Teletone M-957, for the input. But I began to see a considerable amount of wiring. There were, after all, many buffers, latches, holding registers, and interrupt lines running to the processor board. In short, a rather complex design took shape for this section of the project.

One morning in the shower (without a "Eureka" though) a solution came to me. Another processor could be used to control the interface. I finally selected the Intel 8085, a chip that offers simplicity of design, economy of parts, and the option of simple connections for interrupt-driven devices.

The 8085 was assigned the functions of debouncing, access timing, and code conversion of the tone decoder outputs. It would then queue them for the host, in this case the processor board. It would also queue phonemes to be spoken by the Votrax speech chip and it would handle the interrupts generated by that device. Thus, the host would have much, if not all, of the time-dependent functions removed from it and placed in the slave 8085 processor. A later addition, made to the slave's software, allowed a time-out feature that permitted the slave to respond, on its own, with "Please wait a moment" if the host didn't pick up its data within 10 seconds because of a calculation that was in progress.

The 8085 slave processor, in completed form, had 2 kbytes of RAM and an equal amount of ROM. Expansion to 4 or even 8 kbytes of ROM should pose no problems. Another chip, the 8255 PIO is used for the communications interface with the host processor. Clock signals for the 8085 are derived from the DTMF decoder chip, so just a single crystal is used to drive the entire board.

Software for the 8085 was, like the host's, written in C. The only problem encountered in the implementation concerned the timing and synchronization of the host and slave processors.

As mentioned, software development took little time and, within 3 weeks, the program was calculating orbital data. The object code size at this point was about 24 kbytes. At that point I began to wonder about the number of features that could be built into the remaining 4 kbytes of space.

My thoughts turned into real wonder as I found that the speech routine fit easily into 4 kbytes. I then added features to the program until I ran out of room.

Currently, the program can speak the following information on command:

1.) Azimuth and elevation data for all currently visible satellites,

2.) Rise time and azimuth for satellites not currently visible,

3.) Summaries, at 2-minute intervals, of a satellite's azimuth and elevation with optional presentation of Doppler shift, range, and phase,

4.) Keplerian elements currently in use by the program for its calculations, and

5.) The commands necessary to operate the system, i.e., Help for the user.

During software development, I ran into some small problems with the Aztec C-II compiler relating to the ROMable code generation. When the compiler is asked to generate initializers (for example the definitions of the arrays containing the phonemes for the speech), the code was generated in the data segment that the loader then allocated to RAM. Since RAM may not be preset in the way the package was attempting, it was necessary to edit some of the assembly code source files produced by the compiler to remove those segmentation directives, thereby assigning the variables to ROM. There were some components of the supplied library that required modification as well.

Comets

Larry Price, W4RA, President of ARRL, and Lance Collister, WA1JXN, at the ARRL Northwestern Division Convention.

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Specifications: (2M-14C)

BANDWIDTH:	144–150 MHz	BOOM LENGTH:	12'9"
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FEED IMP:	50 ohm unbal.	WT. (LBS):	
BALUN:	4:1,2KW	ELLIPTICITY	3dB Max.
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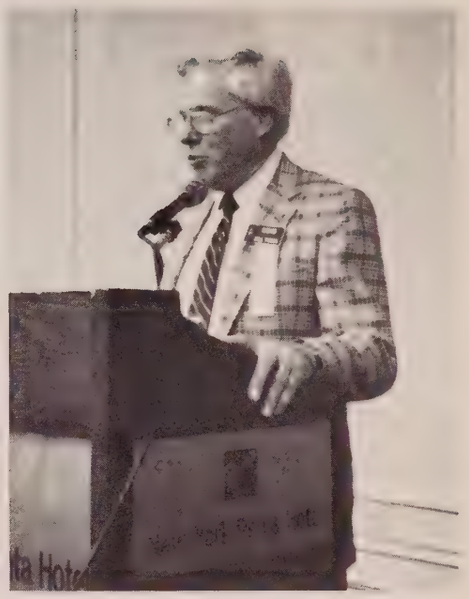
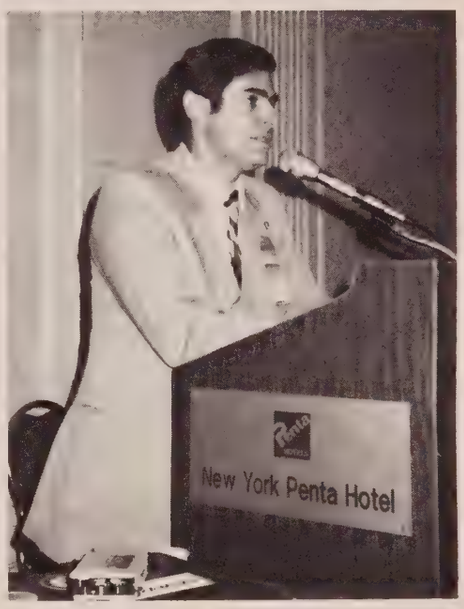
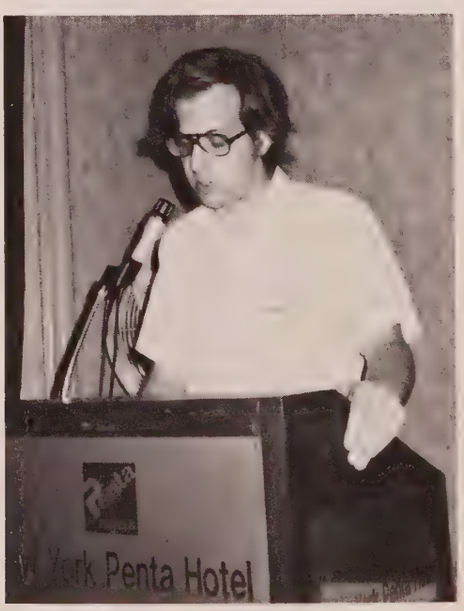






AMSAT officials at the recent NYC Convention. Top to bottom: W3XO, N2CF and KA9Q.

Phase III Spacecraft Thermal Design

By Dick Jansson, WD4FAB

Brutal heat and damaging cold are the realities of space. Designing a satellite to tolerate that environment requires a mix of careful planning, competent designing, and proper materials selection.

Much of the credit for the success of AMSAT-OSCAR 10 lies in its thermal design. And underlying that success has been a knowledge of heat transfer principles and their application to help ensure long and reliable spacecraft life.

Electronic devices that operate in the atmosphere have the advantage of a gaseous environment to aid in the removal of heat by convection. Satellites on the other hand, have neither an atmosphere nor gravity to help the thermal convection process and must rely solely on conduction and radiation. Added to the stricutures are various mission operating parameters, material properties, coatings, and device temperatures that all interact in complex relationships, making the job of thermal design difficult indeed.

Also required in thermal engineering are the complementary requirements of defining a problem and finding its solutions. That is followed by analytic modeling to test the adequacy of the solutions and help make the test selection. A model so developed is then used to evaluate the actual hardware before launch and to help assess post-launch data to aid flight controllers in their decisions concerning spacecraft attitudes and operating modes.

Such earlier satellites as OSCARs 6 and 7 were plagued by overheated batteries, which shortened their useful life. In terms of thermal design, Phase III presented a list of requirements more demanding than those of its predecessors. Accordingly, work on the Phase IIIA spacecraft began shortly after the launch of OSCAR 8 in March 1978. An assessment of mission requirements resulted in a thermal design plan with several major goals, including maximum decoupling of the internal modules and the space environment. The plan had to take into account the extremes of temperature of space and the all important need to keep the battery cells cool — to within a range from $-5°$ to $+10°C$. Also, the temperature in each arm of the spacecraft had to be maintained to within $2°C$ of each other.

Other considerations included the apogee kick motor temperature, which had to be limited to $0°$, and the range of sun angles, which range from $+60°$ to $-60°$. The effects of firing the kick motor plus the amount of heat generated by internal modules also had to be considered.

Although previous design techniques called for maximum coupling between the spacecraft's exterior and the internal modules, isolation, or decoupling, was needed for Phase III to provide long time-constant protection against the powerful thermal effects of motor firing, perigee earth heating, and earth shadowing.

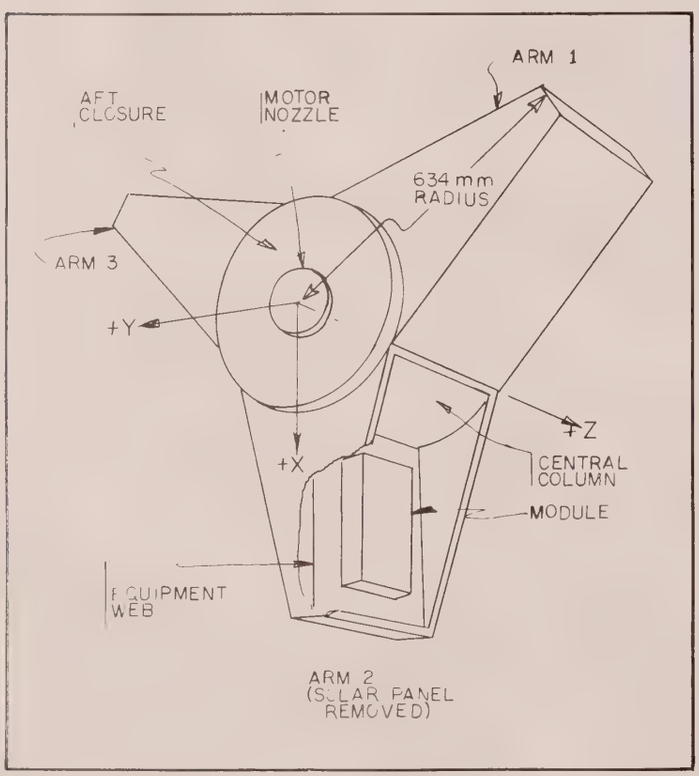
Important Coatings

A practical requirement in the implementation of a spacecraft thermal design is the selection of external coatings. Phase III is large for its power dissipation and the effective surface area must therefore be reduced. That can be either by very low emittance surfaces that are difficult to achieve with accuracy or more simply by in-

sulating large surface areas to remove them from effective thermal radiation heat transfer. Such insulation treatments desensitize the remaining coatings from insidious changes, such as space induced degradations and fabrication tolerances. That insulation approach was selected, and substantial areas of the Phase III design were insulated by the use of multi-layer insulation blankets.

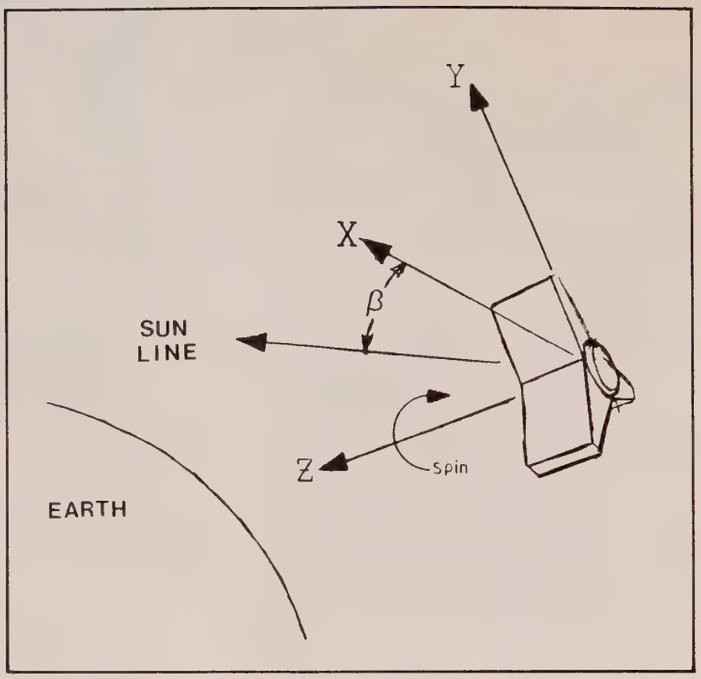
Only a few months prior to the launch of Phase IIIA it was realized that the thermal design was not completely aligned with the developing requirements of some of the internal modules. Solar panels were much warmer than had been expected, creating a hot condition on the transponder transmitter module in Arm 1. Furthermore, the condition caused a 10 °C temperature difference between the two halves of the main battery, located in Arm 1 and Arm 2. A target value of ±2 °C was desired.

Thermal coating studies were quickly redone. Additions to the thermal design definition included a mission change to require performance at higher sun angles with respect to the spacecraft X-Y spin plane. Changes to the coating designs were needed on all three arms with a reduction in the MLI blanket area to expose more surface area and increase the coating sensitivity to apogee motor plume degradation.



Phase IIIA Spacecraft Thermal Model Terminology and Coordinate Reference System.

A decoupled design required that electronic module temperatures could be controlled within reasonable bounds. In general, space electronics must have low power dissipation with correspondingly low package heat fluxes to make temperature control by thermal radiation feasible and practical. The necessary conductive thermal isolation is made possible by non-metalic materials at the



Phase III Geometric Space Reference Definitions and Relationship to the Spacecraft Coordinate Reference System. Z axis = Spacecraft Spin Axis, Nadir at Apogee. β = Angle Between Sun Line and X-Y Plane.

module mounting interface, allowing thermal radiation to be the dominant heat transfer means. The temperatures of individual electronic packages can be adjusted by varying the emittance of the packages, accomplished through the use of various pressure sensitive tapes, even at final spacecraft assembly.

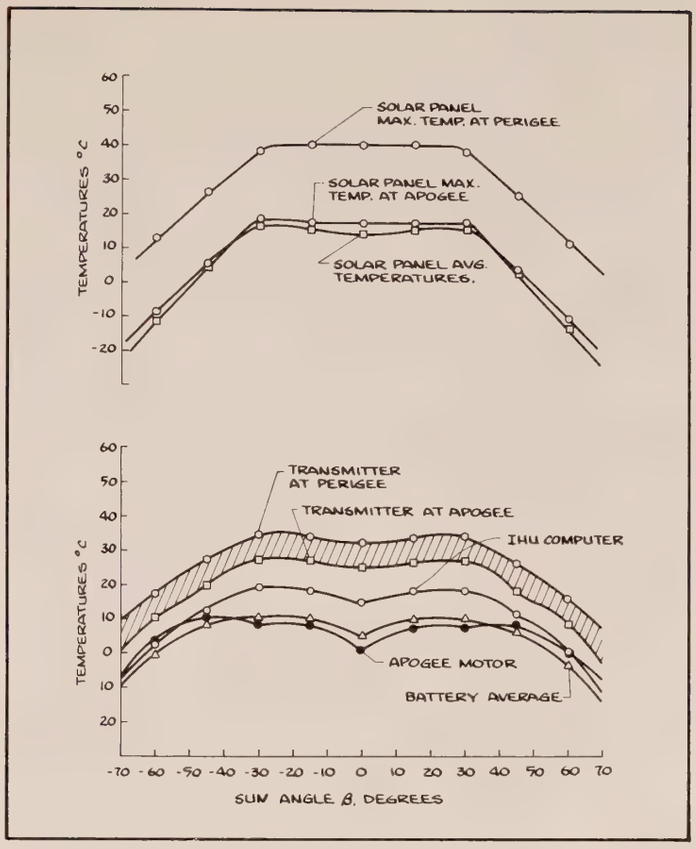
Computer Modeling

By far the largest effort of the Phase III thermal design task was development of a computer model of the spacecraft and exercise of that model in many orbits and configurations. Analytic modeling thereby provides the opportunity to accurately determine the most desirable configuration of the spacecraft long before launch.

For Phase III, the analytic software used was the massive NASA-TRW subsystem called Systems Improved Numerical Differencing Analyzer, or SINDA. Many computational services are provided by SINDA, in addition to its basic analysis of thermal systems, represented by an electrical analog. Creating a thermal model consists of dividing the subject spacecraft into discreet mass lumps or zones, called nodes, and connecting these nodes with a matrix of thermal conductors that provide the heat flow paths.

Assisting the construction of a thermal model was an orthogonal coordinate system established about the spacecraft central axis. Those references describe the orientation of the spacecraft in space and also eliminate confusion among the experimenter's references to locations on the spacecraft.

Completing a thermal model requires the placement of the model in its environment, in this case the space environment of an earth orbit. Worst case earth heating ef-



Phase IIIA Computed Temperatures of Spacecraft Elements as a function of Sun Angle, β. Reconfigured Coatings for Launch into Initial Orbit. 10 April 1980.

fects are achieved when the orbital perigee is over the equator at high noon local time, the sub-solar point. At an apogee of 36,000 km the heating effects of the earth are negligible, which with the long time spent near apogee allows the model to be treated as a steady state thermal computation at this point. These simplifying assumptions eliminated 60% of otherwise useless computations, saving a great deal of computer time.

Constructing an accurate thermal model requires the consideration of many elements: material properties including the distinction between metallic alloys of the same family; radiative properties; orbital mechanics; electronic design; fabrication techniques; and even such miniscule details as the thermal conduction of riveted joints. The Phase III is a fabricated structure of thin sheet aluminum joined with rivets and the initial drawings specified the number, size, and location of these rivets. Thermal conduction across such joints is far from ideal as the effective metalic contact area can be considered to be no larger than three times the rivet diameter. That desciption is used as an example of the detail incorporated into the model.

Thermal coupling between arms of the spacecraft is rather low due to the thin shell construction. Each arm must have a heat balance that is nearly independent of the conditions in the other arms. Analytic treatment of the spacecraft as a simple single node model can be very misleading and the coatings on each arm must be tailored for that arm.

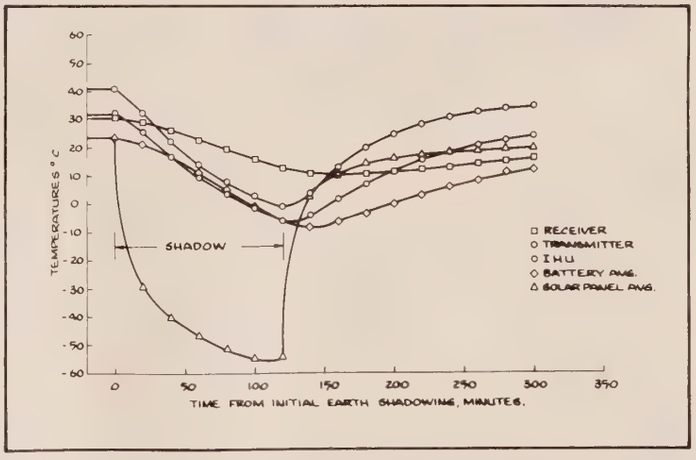
Analyzing the Results

Computational results are presented as curves of temperature as a function of β. A close tracking of the spacecraft fabrication and the adjustment of the analytic model to represent the hardware to meet the thermal design requirements produced the calculated temperature performances shown. For the range of $\beta = -60°$ to $\beta = +60°$ a reasonably flat temperature profile was obtained.

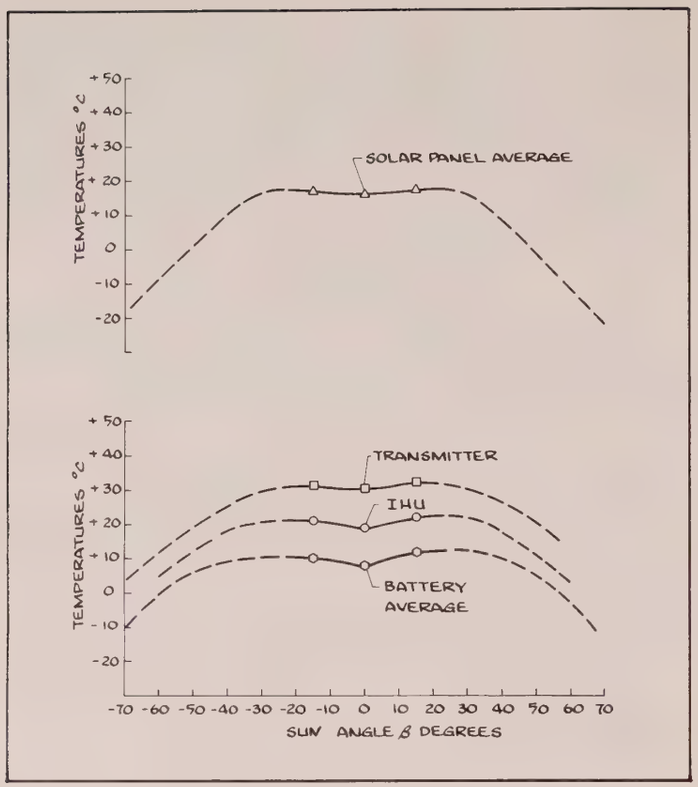
Most of the computations were done for the initial orbit and for the most severe case of lower altitude perigee heating. Final orbit perigees are higher and hence much less thermally dramatic. Motor firing for Phase IIIA was forecast to provide a problem for the spacecraft. The motor that would have been fired was solid propellant fueled and the exhaust products would create undesirable deposits on nearby spacecraft surfaces that would have changed the radiative properties of those surfaces. That is a very complex subject that has caused a considerable problem for spacecraft designers. For Phase IIIB, now OSCAR 10, the motor used hypergolic liquid propellants whose exhaust products remain gaseous and do not create adverse surface deposits.

Numerous special case computations were done, especially for Phase IIIA, for situations such as injection into orbit at a sun angle of 90° and earth shadowing at apogee. The results are shown for a worst case earth shadowing condition of two hours at apogee. That is the condition for which the decoupled thermal design was provided. Note that the temperatures of the internal components did not go as low as -100 °C and that is considered very adequate for their survival. The fact that the solar panels dropped to -55 °C is also quite acceptable.

The motor firing event of both Phase III spacecraft was of further concern. On Phase IIIA the motor was originally designed as an exposed vernier trim motor for an ICBM and there was not a great deal of data for the motor used in an enclosed spacecraft. Most engineering was done on an estimated motor effect basis until early 1980. Personnel at Arnold Air Force Station in Tullaho-

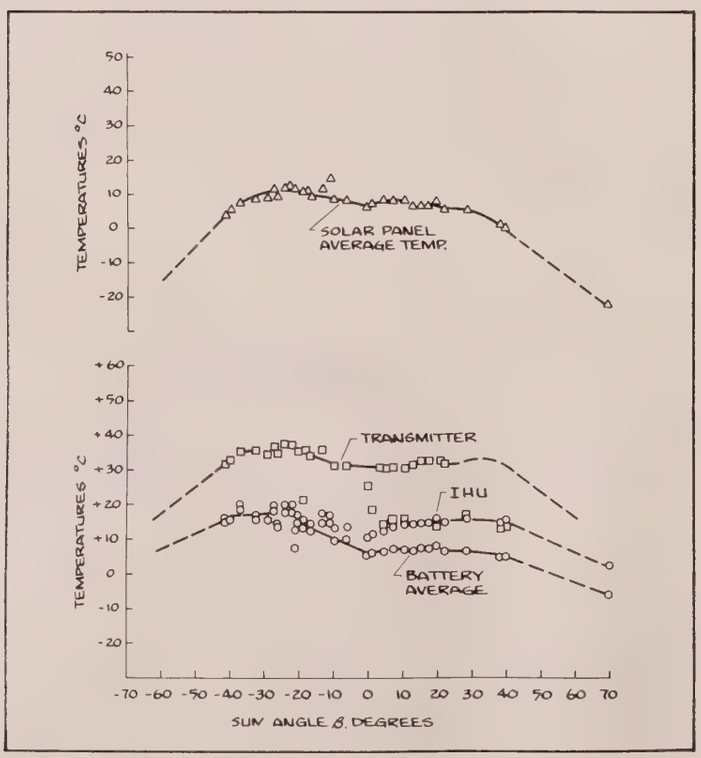


Phase IIIA Computed Temperatures of Spacecraft Elements as a Function of Time of Earth Shadowing and Solar Warm-up. Shadow Time 120 Minutes. β = 0 degrees at Apogee. 11 February 1980.



AMSAT Phase IIIB predicted temperatures on 15 December 1982 are shown above.

ma, Tennessee, helped by providing the results of special instrumentation used during a routine reliability test firing of a sample motor. That data removed a great deal of the uncertainties from the computation. Special modeling directly incorporated the measured motor thermal data into the SINDA model by taking advantage of the ability to incorporate FORTRAN programming statements. Computational results of the motor thermal event resulted in only small temperature variations, that is, the spacecraft structure rose to 3 or 4 °C one hour after firing, the transponder 2.8 °C at 1½ hours, other modules 1.4 °C at 3 to 4 hours, and the batteries 5.4 °C after 1½ hours. It was concluded that those thermal changes would have not been easily observable in actual operation.



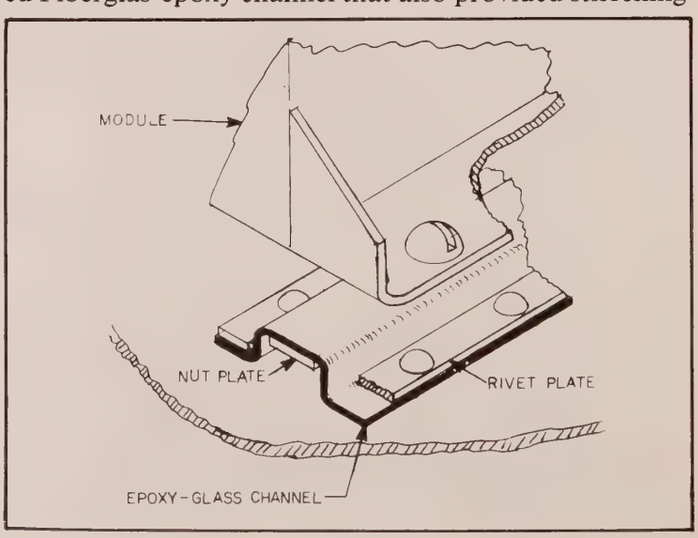
AMSAT-OSCAR 10 Temperatures on 16 May 1984.

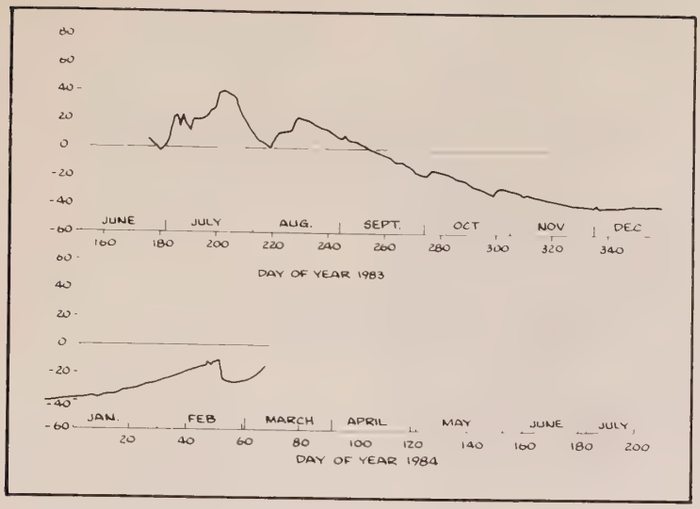
Phase IIIB presented another situation, as the motor was entirely external to the main body of the spacecraft. The motor nozzle was cooled only by radiation and its temperature would rise to 800 °C during its long firing time. While there was no concern for the internal components, the surface temperatures of the adjacent insulation blankets were a problem. Those blankets were designed to isolate the interior and the propellant tank from the space environment. Dangerously high insulation surface temperatures were projected in certain situations. Protective radiation shields were proposed that would have alleviated potential problems, but it was decided that they would not be used. Spacecraft and battery temperatures warmer than those desired are observed for OSCAR 10 when orientations prevail, due to the absence of these blankets. Unfortunately, the long motor burn could not be performed and the potential blanket damage could not be ascertained.

Special Hardware Design

Each module and/or subassembly in the spacecraft required detailed consideration to ensure its thermal design flightworthiness. Electronic modules, as a group, were to be temperature controlled by the emitttance of the module exterior. Deviations from this scheme take the form of the unavoidable thermal conductances associated with its mounting and electrical cable connections (copper wire heat transfer here is an important consideration). Only the transponder transmitter required that its spacecraft mounting be electrically conductive. Most modules were planned to have low thermal emittance aluminum finishes and a higher emmitance surface of black paint was used on the transmitter and the battery charge regulator due to their higher power dissipations.

Providing structurally sound and thermally isolating module mounts required the fabrication of a unique component. The figure below illustrates the specailly molded Fiberglas-epoxy channel that also provided stiffening





AMSAT-OSCAR 10 sun angle vs. time during 1983 and 1984.

to the central plate in each arm of the spacecraft. To fabricate the channel, a two-part aluminum mold, large bolts, and coil springs were used. Four layers of epoxy pre-impregnated glass cloth were applied to the male mold and the assembly was cured in a kitchen oven.

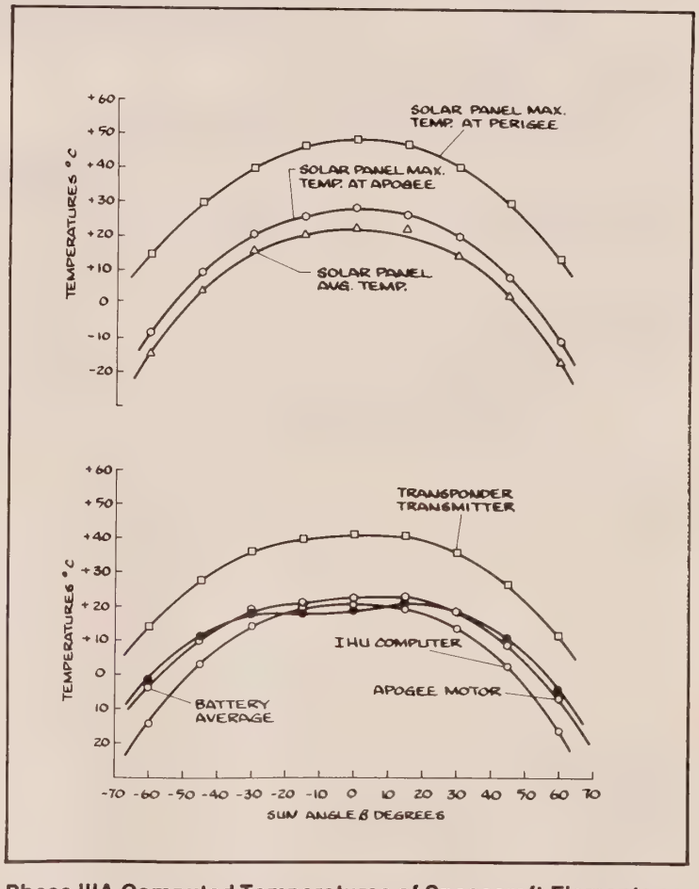
Another spacecraft subsystem that received a thermal treatment was the battery packs. Previously, the nickel-cadmium cells were tightly sandwiched into an aluminum case to avoid the adverse effects of internal cell pressures. That approach suffered from the fact that the dielectric material used between the cells caused them to be thermally insulated, thus creating excessive cell temperatures under certain conditions of battery operation. The solution was to interweave the packed cells with sheets of aluminum foil coupled to the battery case exterior, providing the thermal conductance paths needed yet retaining the cell compression and electrical insulation.

Spacecraft exterior coatings required special consideration. Besides the use of the MLI blankets on the arms, the solar panel edges and the ends of each arm were coated with a second surface of silverized Teflon tape, called the Optical Solar Reflector (OSR). Insulation on the arms is less than full coverage so as to permit added cooling to space. As the spacecraft sun angle inceases, the heating of the solar panels is reduced tending to lower temperatures. High solar heating compensation is provided by the cut-outs in the insulating blankets. In the case of Arm 1, where a larger area of the top and bottom of the arm is exposed for more cooling, the surface is a mixture of 95% OSR and 5% black paint, limiting Arm 1 solar heating.

Fabrication of the MLI blankets was entirely by hand. Sheets of Kapton, 0.005 in. thick, with one side covered with vapor-deposited aluminum, 300 to 500 angstrom thick formed the protective outer sheets of each blanket. Four sheets of 0.00025 in. thick Mylar, with aluminized Kapton on each side, were separated by a Dacron bridal-veil net. That sandwich was stitched together with surgical Dacron thread using surgical needles. Edge separators of thin porous urethane foam were included in the stitching to insure a construction free of interlayer compression, a degrading factor in insulating blankets. While detailed tests of the blankets were not conducted, the thermal performance requirements were also not particularly severe and the probability of achieving design goals was considered good.

Certain areas of the Phase IIIA thermal design were considered somewhat weak and those were addressed in the Phase IIIB effort. Placing the main batteries either in the two low power Arms 2 and 3 or all in one arm was considered essential. The original selection of insulating edge material was poor, due to outgassing effects, with the change made to the previously described material being a substantial improvement. Higher power dissipations in the transponder transmitter and the exposed apogee motor both caused extensive re-analysis of the mission resulting in further changes in the arm coatings. Arm 1, for instance, had no blanket attached at all, while the blankets for the other two arms were modified.

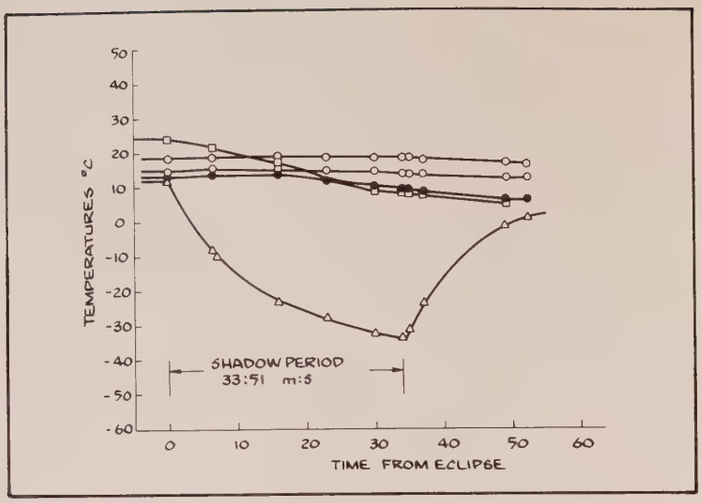
The general spacecraft temperature being somewhat lower than prior OSCARs was a design decision made at the beginning of the program in 1978 to promote longevity in the batteries. This was not a unique decision as NASA data has shown significant life-time/reliability improvements for nickel-cadmium batteries by operating at temperatures near 0 °C. The helium tank lower temperature limit being only specified to 0 °C did not, unfortunately, look at the spacecraft as a whole. The unplanned high sun angle following launch separation, with the resulting low temperatures, only exacerbated



Phase IIIA Computed Temperatures of Spacecraft Elements as a Function of Sun Angle. Initial Preflight Launch Configuration for the Initial Orbit. 2 February 1980.

other problems affecting the helium tank. Low helium gas tank temperatures were also expected from the adiabatic expansion of the gas during motor firing.

While the techniques of spacecraft thermal design are not new, each such encounter provides a unique adventure, a fresh learning ground and a new opportunity to be inventive. Phase IIIB was different from its predecessor and it is expected that Phase IIIC will be different from either, depending upon launch vehicle and specific mission parameters. The AMSAT engineering team is better prepared for the next mission because of its Phase III A and B experiences.



AMSAT-OSCAR 10 temperatures, solar shadowing and eclipse, 8 October 1983 and 15 May 1983.

AMSAT Board Stakes Out Major Goals; Names New Officers

Meeting in Los Angeles for the first time, AMSAT's Board of Directors moved in significant ways to articulate goals and install new officers. The 16 November meeting at the Amfac Hotel, the scene the prior Saturday of the Satellite Symposium and Annual Membership Meeting, had many significant agenda items. The following is the briefest of summaries. Full details will be published at a later date when the minutes of the meeting are made available by AMSAT HQ.

As introduced by Jan King, W3GEY, four organizational goals were endorsed by the Board. These goals are:

1. Recognizing the relative abundance of low earth orbit launch opportunities and their particular relevance to store-and-forward communications techniques on an as-available basis, AMSAT will strive to make effective use of low-cost spacecraft technology to exploit such opportunities.

2. Recognizing the potential value and utility of continuous satellite communications to provide effective public services, AMSAT will strive to develop space systems to fulfill this need.

3. Recognizing the growing value of space science and space research activities to our organization, AMSAT will strive to participate and cooperate with other organizations in pursuing appropriate science and research activities.

4. Recognizing the value of communications services provided by the Phase 3 satellite program, AMSAT will continue to support the program.

Officers elected included John Browning, W6SP, Chairman of the Board, Vern 'Rip' Riportella, WA2LQQ, President, John Champa, K8OCL, Executive Vice President and Acting Vice President for Operations; Jan King, Vice President for Engineering. Art Feller, KB4ZJ, was elected Treasurer and Martha Saragovitz was re-elected Corporate Secretary. Additional officers named subsequently included the following appointments: Bill Brown, K9LF, Vice President, Special Projects; Bill Tynan, W3XO, Vice President for Manned Spacecraft Operations.

In other actions, the Board: Resolved to commend W3IWI on his devotion and creativity as President; decided to meet again not later than March 1985; decided to fund Phase 3C at $50,000 per year for each of two years with 32% of the budget for projects; commended WD4FAB for his project of recruiting and finding tasks for talented volunteers; support the creation of an International Amateur Satellite Service Coordinating Committee as discussed at the Cheltingham, England meeting in July; decided that Phase IV needs more study and groundwork before major commitments could be made towards it; heard of possible Phase 3C integration options; learned that an Ariane 4 launch in mid-1986 was looking favorable for Phase 3C; that Phase 3C could contain Mode B and L transponders, a Mode L digital transponder and an S-band beacon (2.3 GHz.); learned that a PACSAT satellite was at least 1.5 years away and possibly could be launched from a Shuttle from Vandenberg AFB given that the V'Berg launches have a higher orbital inclination and would be thus more useful to Amateurs; heard of improvements in the Area Coordinator team, communications within Operations and the possibility of an Operations Management newsletter; learned of the Teleport STA granted to 21 stations; resolved to commend the ARRL on its superb effort and leadership in connection with the WARC-79 frequency allocations and to endorse the efforts of the ARRL to preserve the 220 MHz band and to have the 1270 MHz space allocation implemented; decided to poll the membership on the matter of sale of mailing lists to outside agencies for the purpose of raising revenues; resolved to support an ARRL DXCC-satellite award providing the award was non-endorsable and that the concept was endorsed as well by AMSAT-DL; discontinue *ORBIT* magazine after #19 and initiate a new, less costly publication early next year.

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F antennas and
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is probably no other
topic that inspires such a
line of conversation than the
of antennas. Hardly a day
when I'm not asked ques-
ke "What type of antenna do
ecommend?" or "What's the
ence between this antenna and
one?" The reason we're so inter-
collinear array
The collinear array was very p
lar among VHF/UHF'ers and
cially EME'ers (Earth-Moon
2 meters and 70 cm (432
high performance VHF
DIPOLE 1 TUNED TO F1 (F1 < Fm)
DIPOLE 2 TUNED TO F2 (F2 > Fm)
Fm = F1 + F2 / 2
PERCENT DIPOLE "STAGGER" = F2 - F1 / Fm x 100%
The VFO dial calibration problem is
a matter of fine tuning the VFO and
HFO in accordance with the proce-
ure described here. The Heathkit
ocedure does not calibrate the fre-
ency of the HFO; it also does not
tch in the offset capacitor (C55)
ing VFO calibration so that the dial
read transmit frequency.
dification procedure
move the following resistors:
R82, R84, R85, R87, R88,
am radi
CHNIQUE
the output power of the final amplifi
stages at high values of SWR.
One of the antennas I discussed was
the crossed-dipole array described by
Mason Logan, K4MT, in the May, 1983,
issue of this magazine. His basic an-
enna design is shown in fig. 1. The
easured SWR curve of this antenna
hown in fig. 2. I suggested in my
per column that a matching coil
be required at the antenna feed-
bring the impedance closer to
Shortly after publication, I received

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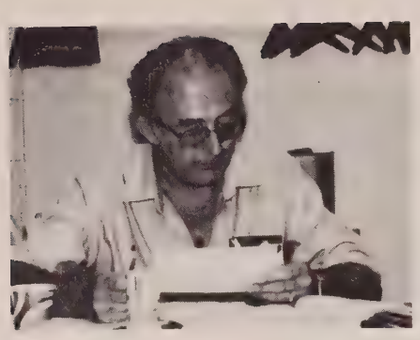

G3IOR

Worldwide Satellite Activity

By Pat Gowen,* G3IOR

Our last column in *Orbit* No. 18 described the problem that was evidenced by our latest satellite UoSAT-AMSAT 11. We were anxiously awaiting either command acceptance or for the lapse of 21 days to restore the receive capability of the command system. After much longer than the three week auto-beacon-off period, there was still no response.

Enthusiastic helpers around the earth earnestly searched for UO-11, both visually, by radar from Lee, ZD8LM, and by the Surrey team looking for any signals using the radio telescope at Jodrell Bank. An enormous number of devotees patiently searched the skies looking at all possible frequencies that might be emanated by the spacecraft.

Finally at 1403 and 1542 UTC on 11 May, Finn, OX3FS, using the 200 ft. S.R.I. dish at Sondestrom Fiord, Greenland, was able to confirm the identification of +7 dBm signals from the local oscillator of the 1.2 GHz command receiver, thus confirming orbital parameters. The good news was rushed to KD6DG, thence via G3AAJ to the University of Surrey team, which immediately attempted to command the quiescent satellite back to life.

Early attempts on the 2-meter command channel met with failure. But, subsequently a 70-cm command brought the long silent 145.825-MHz beacon back to life at 1101 UTC on 15 May to the delight of all, and the astonishment of many. Deep analysis of the telemetry is in progress in the hope of establishing the exact cause of the problem so as to prevent its re-occurrence. By the time that you read this, it is hoped that all experiments on board will be undergoing testing, including the new expanded large vocabulary Digitalker, the PACSAT channel, the impact counter, and the earth imaging system. All are anxious to see what picture emerges.

AMSAT-OSCAR 10 is the mainstay of satellite communications at this time, with new countries appearing regularly. Over 100 DXCC countries have now activated the satellite with 4S7 (Belgian DX-pedition), 9H1, ISØ, T77, UC2, VP5, 9Y4, and OA4 now active. Top scores come from ON7HP and K5ADQ, both with 94 worked, followed by W6KH and

Peter, ON7HP, leading scorer on OSCAR 10, at home in his shack in Antwerp.

Antenna system at the QTH of Peter, ON7HP.

G3IOR each with 90. Some interesting experiments have been taking place in addition to DX traffic. Dave, G4CUO, got cracking on his computer and calculated some optimum times that would permit trans-satellite contacts by transmitting to OSCAR 10, its downlink then going on 145.92 MHz to RS6, whose downlink would appear on around 29.413 MHz, according to the Doppler shift. On the first two tests, nothing was heard, but, at 0711 on 7 May, when OSCAR 10 was above RADIO-6, over the Libya/Algeria border, a two-way RST 559 CW QSO was made between G4CUO and G3IOR. Since then, at mutually suitable times, further contacts and a number of 'cross-band' QSOs have been accomplished. The basic requirements called for are small numbers of low power users on both RS and AO-10, with the latter approaching perigee but prior to the turn-off time. If possible OSCAR 10 should be in a position where it is directing maximum signal strength onto its lower orbiting fellow.

Norman, G8SMQ, calculated the optimum time when the apogee was at midway point between England and New Zealand (virtually antipodeal) and organized activity to try to make the first ZL/G QSO. Previous evenings had indicated that the AO-10 downlink could often be heard even when the satellite was up to 1.4° below the horizon and the uplink station had access at 0.45° under suitable conditions. During the ideal day and time, the evening of 7 May, torrential rain and gales were sweeping eastern England after an eight week drought. As one might expect, nothing was heard from the satellite until it was at least 0.6° above the horizon. The chance may come again in three years time.!

Due to the poverty of hf communications between LZ and 9N1 during the Bulgarian Everest expedition, moves were being made to use OSCAR 10 for dependable contact over the period of the event. Sadly, after conquering the peak, the leading climber fell to his death.

The Stoner challenge cup has seized the enthusiasm of many Oscarators, with a plentiful supply of numbers being exchanged. In early May, SV1OE was already giving a serial number in the four-hundreds, a good indication in itself of the steadily rising use of the satellite.

Bill, KØRZ, reports that Mode L is improving, with signals now some 6 dB higher and with far less intermodulation from the beacon keying. He has now worked 47 of the 71 stations reported active, mainly in the 436.480 - 436.580 MHz downlink band section. New stations include DK1UV, JA1SYK, WB5LUA, DL7ZL, GW3XYW, JA1UHY, KL7GNG, DK2LR, G8HVY, JR1WZI DJ9EQ, HB9CAI, KØKE, YU3UMV, DJ5BC, I5MSH, JA4CDC, OE1HAB, DC6YU, DL9GU, I7UGO, JA4TTS, OE1VKW, DL7APV, JA1AUH, OE9ERI, W4WSR, DK1TB, G4KGC, JG1SSK, OK1KIR, DK2ZF, HB9BM, JA3EGY, VE4MA, DF3XG, HB9MKQ, JA6DZO, DL3NQ, I5CTE, JA4GVA, DJ5KQ, I6PNN, K6GXJ, DJ7BG, IW3QIO, KA6HZO, DFØEME, JE1HJJ, and OE1ERC/1. Uplink powers of users varies from 10 to 500 W, and antennae from 1-meter dishes and single long Yagis to large stacked arrays and 26-ft. dishes. Quite a sortie of downlink aerial systems are used as well. Bill reconfirms that the path to success on Mode L is dependent upon a good downlink antenna and receiver, with two long Yagis (or helices) with a masthead-mounted GaAsFET being the absolute minimum downlink system possible for results. He can now identify that the transponder, like its Mode B counterpart, also suffers from attenuation by agc action when uplink powers of 25 kW eirp are employed.

Adam, SP9DH, reports that to his delight, he has now worked his 100th DXCC country, DL3ZM/YV5, by satellite. Adam has cw only for OSCAR 10, from a low-power tripler, but is a regular on all the satellites, having been fully active since OSCAR 6. He has worked three stations (DJ2RE, OK3CDI/AU, G3IOR) on every satellite and every mode. SP9EVP leads the Polish OSCAR 10 field with 6 continents, 29 Zones, 64 countries, and 398 different stations, followed by SP9DH, SP6ASD, SP2AOZ, SP5AGT, SP5FHC, SP6LB, and SP5HEJ, with SP2IHG, SP2DFW, and SP6JLW also reported active.

Both ON7HP, Peter, and DL1CF

QTH and Antenna system of DL1CF.

Vassil, LZ1AB, in his shack at Sofia, Bulgaria. In addition to his satellite communications, Vassil makes many Es, MS, Tropo contacts, and is looking forwards to EME soon.

Satellite antennas of Heinz, DL1CF.

On the way to the Aaland Island OSCAR DX-Pedition. Kaj, OH6EH, Pekka, OH6GO, and Olli, OH2XN are loaded and ready for the ferry trip across.

report having finalized their WAS Satellite, with Heinz receiving the first certificate for Europe. Jesus, EA4AO, has been active on OSCAR 10 with very low power and a non-elevatable antenna. His QTH is a four-story building, unfortunately with a 14-story block between him and the path for W/VE. He has built the W2GN linear (*QST* August 1982) and will be feeding this into a 7-turn helix with an az/el mount. A 10 + 10 crossed Yagi is used for the downlink. Despite the current limitations, Jesus has worked W8VXH, K9NO, VE2L1, PY6HL, ZS6's AXT and BMS, VK5QR and 8OB, UAØ's LFK and SBI, UL7GBD and DD, UA9ACN, and 58 different JA stations, plus many Europeans.

Very little information has come in this time to sustain our column on current happenings, so let us take a little time to think about potential plans for the future. AMSAT is now thinking of Phase IV in the form of a cluster of interconnecting geosynchronous satellites, possible Mode L. The project appears to be technically, financially, and administratively possible, and the views of our user members are urgently sought as to how they sense the viability and feasibility. Undoubtedly some may feel that such a surefire global communications system might take the fun out of things while others may feel that the cost and complexity of acquiring suitable equipment would detract from their possibility of using such a system. With local gateway stations, one area could build a local repeater system funded by users and built by technical people expert in the art of UHF and digital construction. With Ariane 4 laun-

OH2XN and OH6GO assembling a 2-meter crossed Yagi downlink antenna in the deep snow prior to its mounting. (Photo by OH6EH)

cher, it would be feasible to launch a hexagon of GEOSATs, depositing them where required from the single launch, and/or thrusting the GEOSAT to the equatorial longitude desired.

AMSAT now has highly advanced technical groups around the world, each of which might wish to contribute its own particular sphere of excellence. For instance, perhaps all the battery-charge regulators could come from the AMSAT-HA group at the Technical Institute of Budapest with, perhaps the University of Surrey providing all the space-frames, and so on. Thus the burden, work load and effort would be shared and contributed to a true international satellite system for all.

Heinz, DL1CF (ex DB2OS) has been carefully monitoring OSCAR 10, especially on Monday QRP days, and has come up with a list of 54 stations that exceeded the beacon level by between 2 and 4 S units. In most cases he noted the claimed power output and antenna system to judge the actual eirp. The list shows seven OE stations, 23 DLs, and a general sortie of European stations that are grossly exceeding the required power. Only three of the offenders are outside Europe!

PACSAT fans will find some interesting reading in the VITA news of April 1984 on the development and applications of this medium. After an initial block, packet radio has been approved for the U.K. One station is already going, with three amateurs (G8QR, G3LDI, G3PMQ) almost ready in Norwich alone complete with TAPR boards.

OH6EH and OH2XN mounting the antenna system at the Aaland Island DX-pedition.

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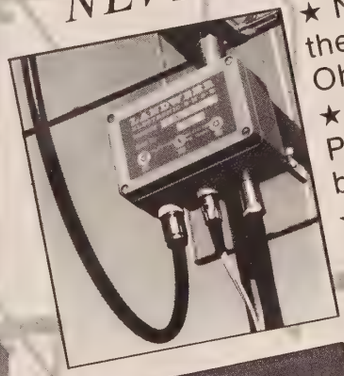

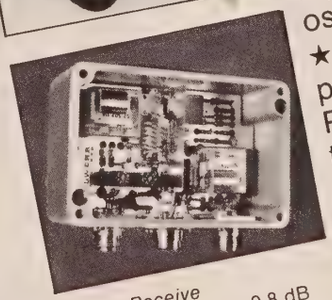

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Orbit Predictions

By KA9Q

Satellite:	*OSCAR-9*
Catalog number:	12888
Epoch time:	84245.38097269
Sat Sep 1 09:08:36.40 1984 UTC	
Element set:	677
Inclination:	97.5988 deg
RA of node:	221.1855 deg
Eccentricity:	0.0002408
Arg of perigee:	164.0344 deg
Mean anomaly:	196.1002 deg
Mean motion:	15.26295495 rev/day
Decay rate:	1.913e-05 rev/day 2
Epoch rev:	16116
Semi major axis:	6862.000 km
Anom period:	94.346082 min
Apogee:	487.097 km
Perigee:	483.792 km
Ref perigee:	2435.41080159
Sat Sep 1 09:51:33.257 1984 UTC	
Beacon:	145.8250 MHz

Satellite:	*OSCAR-10*
Catalog number:	14129
Epoch time:	84245.97247851
Sat Sep1 23:20:22.143 1984 UTC	
Element set:	122
Inclination:	25.6768 deg
RA of node:	180.4720 deg
Eccentricity:	0.6066575
Arg of perigee:	302.6109 deg
Mean anomaly:	12.7882 deg
Mean motion:	2.05850089 rev/day
Decay rate:	-9.1e-07 rev/day 2
Epoch rev:	919
Semi major axis:	26106.073 km
Anom period:	699.538196 min
Apogee:	35568.222 km
Perigee:	3893.332 km
Ref perigee:	2435.95522189
Sat Sep 1 22:55:31.170 1984 UTC	
Beacon:	145.8100 MHz

Satellite:	*OSCAR-11*
Catalog number:	14781
Epoch time:	84238.10950802
Sat Aug 25 02:37:41.492 1984 UTC	
Element set:	40
Inclination:	98.2346 deg
RA of node:	300.0812 deg
Eccentricity:	0.0014750
Arg of perigee:	73.2178 deg
Mean anomaly:	287.0654 deg
Mean motion:	14.61895430 rev/day
Decay rate:	7.7e-07 rev/day 2
Epoch rev:	2577
Semi major axis:	7062.277 km
Anom period:	98.502257 min
Apogee:	713.749 km
Perigee:	692.915 km
Ref perigee:	2428.12336647
Sat Aug 25 02:57:38.863 1984 UTC	
Beacon:	145.8260 MHz

Satellite:	*RS-3*
Catalog number:	12997
Epoch time:	84245.00250300
Sat Sep 1 00:03:36.259 1984 UTC	
Element set:	101
Inclination:	82.9566 deg
RA of node:	91.0443 deg
Eccentricity:	0.0058038
Arg of perigee:	188.5482 deg
Mean anomaly:	171.4626 deg
Mean motion:	12.15588021 rev/day
Decay rate:	4e-08 rev/day 2
Epoch rev:	12014
Semi major axis:	7987.327 km
Anom period:	118.461187 min
Apogee:	1656.004 km
Perigee:	1563.291 km
Ref perigee:	2434.96332155
Fri Aug 31 23:07:10.982 1984 UTC	

Satellite:	*RS-4*
Catalog number:	13000
Epoch time:	84242.60334243
Wed Aug 29 14:28:48.785 1984 UTC	
Element set:	216
Inclination:	82.9593 deg
RA of node:	101.8481 deg
Eccentricity:	0.0017274
Arg of perigee:	283.4061 deg
Mean anomaly:	76.4961 deg
Mean motion:	12.06667459 rev/day
Decay rate:	0 rev/day 2
Epoch rev:	11894
Semi major axis:	8026.669 km
Anom period:	119.336938 min
Apogee:	1682.321 km
Perigee:	1654.590 km
Ref perigee:	2432.58573284
Wed Aug 29 14:03:27.317 1984 UTC	

Satellite:	*RS-5*
Catalog number:	12999
Epoch time:	84239.02868601
Sun Aug 26 00:41:18.471 1984 UTC	
Element set:	186
Inclination:	82.9592 deg
RA of node:	105.3413 deg
Eccentricity:	0.0010404
Arg of perigee:	321.1777 deg
Mean anomaly:	38.8554 deg
Mean motion:	12.05058074 rev/day
Decay rate:	3e-08 rev/day 2
Epoch rev:	11835
Semi major axis:	8033.819 km
Anom period:	119.496316 min
Apogee:	1672.311 km
Perigee:	1655.594 km
Ref perigee:	2429.01972946
Sun Aug 26 00:28:24.625 1984 UTC	

Satellite:	*RS-6*
Catalog number:	13002
Epoch time:	84247.06383140
Mon Sep 3 01:31:55.32 1984 UTC	
Element set:	87
Inclination:	82.9569 deg
RA of node:	92.0551 deg
Eccentricity:	0.0049459
Arg of perigee:	203.3380 deg
Mean anomaly:	156.5438 deg
Mean motion:	12.13562715 rev/day
Decay rate:	4e-08 rev/day 2
Epoch rev:	12016
Semi major axis:	7996.217 km
Anom period:	118.658886 min
Apogee:	1660.926 km
Perigee:	1581.829 km
Ref perigee:	2437.02799939
Mon Sep 3 00:40:19.147 1984 UTC	

Satellite:	*RS-7*
Catalog number:	13001
Epoch time:	84245.10146566
Sat Sep 1 02:26:06.633 1984 UTC	
Element set:	170
Inclination:	82.9569 deg
RA of node:	98.1893 deg
Eccentricity:	0.0021026
Arg of perigee:	233.9609 deg
Mean anomaly:	125.9506 deg
Mean motion:	12.08686173 rev/day
Decay rate:	4e-08 rev/day 2
Epoch rev:	11944
Semi major axis:	8017.724 km
Anom period:	119.137625 min
Apogee:	1670.210 km
Perigee:	1636.494 km
Ref perigee:	2435.07251995
Sat Sep 1 01:44:25.723 1984 UTC	

Satellite:	*RS-8*
Catalog number:	12998
Epoch time:	84246.07306059
Sun Sep 2 01:45:12.434 1984 UTC	
Element set:	289
Inclination:	82.9585 deg
RA of node:	103.6099 deg
Eccentricity:	0.0019660
Arg of perigee:	359.3119 deg
Mean anomaly:	0.7907 deg
Mean motion:	12.02947164 rev/day
Decay rate:	4e-08 rev/day 2
Epoch rev:	11899
Semi major axis:	8043.221 km
Anom period:	119.706006 min
Apogee:	1680.892 km
Perigee:	1649.266 km
Ref perigee:	2436.07287801
Sun Sep 2 01:44:56.659 1984 UTC	

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2 Watts In—23 Watts Out
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2 Watts In—40 Watts Out
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26th - ZS6BTD

September, 84
13th - VE3KRP
18th - N3DIP

October, 84
3rd - Keith Pugh
4th - AB1K
8th - HK1BYM
10th - Bill Reed
14th - KAØGON
26th - Kenneth Baker
31st - Lawrence Roll

November, 84
2nd - WB8LBU
10th - KY7J
12th - WAØQJK
22nd - K8MU

December, 84
21st - WD4HWO
25th - Nina McKittrick

January, 85
8th - Edward Demarest
15th - Ken Tessneer
20th - N3CBX
21st - Margaret L. Prest
30th - Mack Jordan

February, 85
20th - John Camp

March, 85
7th - N4HY
23rd - Bob Stricklin

July, 85
4th - W1MJ

Others
W1WM
KB2M
KB3DU
K5BPA
VE7CFX
ACØE
Roger Amidon
Winston Center
Jim Elliott
D.M. Farmer
Don Fisher
Don Knollinger
W.C. Louden

AMSAT News

Letters To The Editor Department

Among the pleasures of editing a widely read newsletter are the occasional golden nuggets that appear in one's mailbag. Here's a pretty good "fer instance."

Dear Rip:

I have just returned from a trip to the Peoples Republic of China where I was very pleased to learn that BY1PK in Beijing (formerly Peking) is set up for OSCAR 10 operations.

I was there with my wife and three children and we spent a fascinating afternoon at the BY1PK station. Our guide, after quite a bit of investigation, finally discovered the address and telephone number of the Institute where the station is located and set up an appointment for us to meet the three key men, Mr. Ton, Mr. Wang, and Mr. Yan.

We were about half an hour late because our driver could not find the Institute, and I was very embarrassed that Mr. Wang had been waiting out on the street for us. He led us up the five flights of stairs for some tea and discussion of Amateur Radio.

Going into the building we could see an array of 435 MHz and 145 MHz circularly polarized antennas with azimuth and elevation rotors and a large tribander. Thus, when we sat down for tea, I immediately asked about their OSCAR 10 operations. Unfortunately, communication was quite difficult since our guide knew no ham radio terms and since the Chinese hams spoke only Chinese. We did understand, however, that they had no way of figuring out where the satellite was. I offered to send them a printout for the next 18 months, and they were extremely happy.

With this promise, we moved into the shack — and to my amazement, not only did they have an array of very fancy and complete hf, vhf and uhf equipment, but also on a table to the left was an Apple II which VE7BC had given to the station. I exclaimed immediately that they could use the Apple to locate OSCAR 10, but they said that the computer did not work since it was missing a part.

Meanwhile, however, my 11 year old daughter had located a pile of about 10 disks, had inserted one of them, and was playing Pacman. Thus the computer was working. To boot, one of the disks was marked "W3IWI"!!! My 15 year old son had soon pushed his sister aside trying to run Tom's program, but the disk would not boot. We needed DOS and there was no Apple disk to be found. A careful testing of all the disks which were there, however, led to the discovery of DOS 3.3 on one of the game disks and we were in business.

The next problem was that the only orbital elements on the disk were for OSCARS 7, 8 and the famous "submarine trajectory" into the water which Tom inserted in the early version of his program. Where could we find a new set of elements? I knew that *QST* had published them last year, and I had seen a copy of *QST* in the shack, but I was afraid that they had stopped publishing them this year. I was wrong, however. The March *QST* set forth a full set of Keplerian elements, signed by Phil Karn and ten minutes later, after computing the latitude and longitude of Beijing in west degrees from the big world map on the wall centered on China, the little Apple was printing out up-to-date tracking. Unfortunately, the satellite was not within range.

Our next challenge was to teach the Chinese how to run the program and with our French speaking guide, to whom we translated the program, and the Chinese hams taking notes in their language, it took about two hours before they were running the program. Once it was running, however, it would be hard to describe their joy. They insisted that I sit down and play on hf.

By this time it was 5:30 in the afternoon, or 16:30 GMT. The band was open to the west coast and I had a wonderful time. Unfortunately for DX lovers, I prefer talking to working a pileup and I spoke to five hams and unsuccessfully tried to raise a fellow ham from 9-land. Only Californians seemed awake.

Our new Chinese friends would have been very happy for me to stay, but we had another commitment. They had me sign a form in Chinese which I could not understand but which they explained gave me the right to operate the station and they invited me back as soon as possible.

Obviously, I now hope to work them on OSCAR 10 but I am afraid that that will be very difficult since their English pretty much rules out ssb contacts, and my cw is nil. I have written them, however, and hope to hear back.

Best 73's,
K9LF

Annual Meeting Place, Date Set

The Second Annual AMSAT Technical Symposium and the 1984 Annual Membership Meeting have been firmly scheduled for Saturday 10 November 1984. The specific day was selected following careful consideration of all available individual preference comments.

The location will be the Amfac (formerly Airport Marina) Hotel at the corner of Lincoln and Manchester, on the north side of Los Angeles International Airport (LAX). The address is 8601 Lincoln Blvd., Los Angeles, Ca 90045. Telephone: (213) 670-8111. The Amfac provides the following amenities: Free van service from LAX scheduled each ten minutes; 24-hour restaurant and cocktail lounge; ample free parking; golf and tennis across the street; exercise facilities and swimming pool; numerous meeting rooms; catering arrangements; 750 rooms and 7 suites. Prices are moderate and major credit cards are accepted. A block of "corporate rate" rooms has been set aside for AMSAT use. Room reservations should be made directly with the hotel.

Facilities Chairman is Dennis Dinga, N6DD. Dennis will be handling arrangements for the planned luncheon and dinner on the day of the meeting. His address is P.O. Box 4111, Diamond Bar, CA 91765.

Dr. Cleyon Yowell, AD6P will serve as Symposium Technical Chairman. A call for papers has been issued. Submissions should be sent to Cleyon at: The Aerospace Corporation, Mail Station M4-930, P.O. Box 92957, Los Angeles, CA 90009. His telephone is (213) 615-4234.

Satellite Technical Meeting Reported

A meeting of many of the national groups interested in the construction of amateur satellites was held during the period June 30 through July 3 at Hotel de !a Bere in the vincinty of Cheltenham, England. In attendance were the following invited representatives: Ian Ashley ZL1AOX, Dick Daniels W4PUJ, Robin Gape G8DQX, Bandi Gschwindt HA5WH, Werner Haas DJ5KQ, Gordon Hardman KE3D, Phil Karn KA9Q, Jan King W3GEY, HansPeter Kuhlen DK1YQ, Karl Meinzer DJ4ZC, Harold Price NK6K, Randy Smith VE1SAT/VE6, Martin Sweeting G3YJO and Dave Woodhall ZS6BNT. Not in attendance were invited representatives from the technical groups of JAMSAT and RACE.

On the agenda were the following main items:

1) Review of AO-10 performance and future scheduling of spacecraft operations.
2) Review of the PACSAT mission.
3) Review of the UO-11 spacecraft status.
4) Review of the Ariane-4 launch opportunity.
5) Review of new technologies required for future amateur satellites.

Due to the final orbit obtained by AO-10, a set of operating procedures were required that would deal with the upcoming eclipse and sun angle constraints expected over the next two year period. The schedule selected is responsive to the reduced power per orbit and the requirement to off-point the satellite from its optimum attitude in order to minimize thermal and power effects caused by poor sun angles. At the same time attempts were made to respond to a variety of user operating requests.

A modified general beacon (145.810 MHz) schedule was also adopted that more equally shares time between Morse code, 50 baud RTTY and 400 BPS PSK telemetry and reduces the time between successive transmissions of any type.

The details of these schedules will be announced by usual amateur satellite society sources within the next few weeks. They will be in effect by early August as this is the time required to finalize the spacecraft maneuver and implement the needed software.

Regarding future changes to the satellite's schedule, the amateur satellite technical group present adopted the following proposal for review and adoption by the world wide amateur satellite societies:

Proposal

For the Formation of an International Amateur Satellite Service Coordination Committee.

This group, recognizing that:

1) The launch of a satellite system represents the creation of a significant resource for the use of all radio amateurs;
2) The mission requirements of the groups providing a new satellite system are of primary importance;
3) The operational aspects of the amateur satellite service must be carefully identified, planned and managed; and
4) The freedom of the individual national and international groups to negotiate and plan new missions independent of external constraints must be maintained,

Proposes the formation of an international amateur satellite service coordinating committee, whose mandate shall be to:

1) Establish technical and operational standards for the amateur satellite service;
2) Plan and coordinate the orbital operations of each portion of a system which may be released by the groups which launched the system; and
3) Interface with the International Amateur Radio Union to ensure that the best interests of all radio amateurs are given due consideration in this planning process,

And further proposes that:

Membership in this committee be limited to those groups who have as a primary interest the provision and utilization of amateur satellite services, as evidenced by their charters or constitutions, and to such further groups as the committee shall determine advisable. (End of Proposal)

No decsions regarding PACSAT were taken by the assembled group. Considerable discussion was held concerning the need for coordination of packet radio standards world wide. Considerable concern was raised that the JAS-1 packet experiment is unlikely to be compatible with the PACSAT standards on the basis of data rate and modulation type. In general, it was felt that more work was necessary to adopt true international standards for this mode of communications.

No decisions regarding UO-11 were taken by the assembled group. M. Sweeting reported that the spacecraft would be put into service and the experiment program initiated as soon as the boom deployment was complete which was expected in approximately two weeks time. (Boom was deployed successfully 24 July.—Ed.)

The Ariane-4 launch opportunity was reviewed. ESA has offered AMSAT-DL a firm launch contract for 290,000 European Accounting Units on the Ariane-4 test Launch. The contract is expected to be signed in late July.

Three candidate missions were discussed. These included an Astroid encounter probe, an advanced Phase IV satellite system concept and a modified Phase III satellite. The first two candidates were given lower possibility of success due to time and fiscal constraints. This is particularly true due to the high launch cost being imposed by ESA on this launch. The Asteriod encounter probe was not discussed further. The Phase IV concept presented by W3GEY was given serious consideration for future opportunities and W3GEY, DJ4ZC and G3YJO will continue to discuss and define this concept.

The Phase IIIC satellite to be incorporated on Ariane-4 will contain all of the hardware included aboard AO-10 but with the following additions or modifications:

1) A modified kick motor using a plasma propulsion technology.
2) A modified Mode-L transponder with improved efficiency.
3) An S-Band beacon experiment.
4) A packet radio and beacon unit.

The later unit will be a store-and-forward device with approximately 1 megabyte of memory. In addition, it may have a mode of operation allowing straight regeneration of data as would be of use by gateway nodes internationally. The same unit will be capable of using the large memory for storage of beacon messages which will be transmitted in 300 or 1200 bps FSK or PSK. The packet mode is expected to use 2400 bps PSK.

The Phase IIIC satellite will be constructed by all of the groups attending the meeting. Work assignments were made so that progress on the new satellite may begin immediately.

A variety of spacecraft technologies were discussed during the last day of the conference. The intent was to identify technologies needed for future amateur satellite missions. Included in the presentations were propulsion technologies, attitude control technologies and improvements in ranging/orbit determination technology.

It was felt by most of the participants that the meeting accomplished its intended objectives and was much needed. The conference again demonstrated the value of international cooperation and participation as the amateur satellite service matures.

New Area Coordinators Announced

Chief Area Coordinator Jim McKim, WØCY, has announced the recent appointment of three additional Area Coordinators. They are:

Don E. Knollinger, WB8ZTV, Moundsville, WV; Bruce Power, WD4HWO, Tallahassee, FL; and Stephen Peterson, KI7L, Salt Lake City, UT.

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P220VDA	220-225	<1.2	15	0	DGFET	$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	$79.95
P432VD	420-450	<1.8	15	−20	Bipolar	$32.95
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SP50VD	50-54	<1.4	15	0	DGFET	$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	$109.95
SP144VD	144-148	<1.6	15	0	DGFET	$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	$109.95
SP220VD	220-225	<1.9	15	0	DGFET	$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	$109.95
SP432VD	420-450	<1.9	15	−20	Bipolar	$62.95
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AMSAT heartily congratulates the new appointees and wishes them well as they take up their new duties in helping others get aboard the AMSAT bandwagon.

Project OSCAR Calendars Spur Big Donation

Project OSCAR, Inc. recently announced the sale of Orbital Calendars has once again been a successful fund raiser. In addition to the proceeds of the sale of these Calendars which are sold by AMSAT at various hamfests and conventions, a check for $1,000 has been sent to AMSAT. Project OSCAR has sent these monies to be used as AMSAT's Officers decide best serves the Amateur Satellite Community in furthering the Amateur Satellite Program. Congratulations to all who helped make the Calendar a success again this year! AMSAT sincerely thanks all Project OSCAR members for their continued high level of support!

Kettering's Perry Retires

Geoffrey Perry, Headmaster of the Kettering Boys School north of London, England has retired. For 27 of his 30 years at Kettering he had led students in a fascinating, sometimes brilliant study of foreign satellite activity. His expertise in Soviet satellite monitoring made him a favorite among the world's journalists. He would often provide tantalyzing hints based on his observations made with the barest of equipment. His receivers were World War II vintage for the most part. His total computer capacity was often held in his hand; a hand calculator. Nevertheless he learned much about the Soviet satellite operations with the help of a bright crop of eager students.

Notoriety first came to Perry and Kettering when in late 1977 he and his students predicted the demise of Cosmos 954, a Soviet ocean surveillance radar satellite. Cosmos 954 was nuclear powered and posed a significant threat.

In January 1978 the U.S. notified its allies of the imminent reentry of Cosmos 954. Kettering had predicted January 25. It fell on Northwest Territories, Canada, on January 24.

Then in November, 1979, Perry noticed unusual activity in a Soviet photo reconnaissance satellite. Something clearly was about to happen in the Himalayas. One month later the Soviets invaded Afghanistan.

Perry was the subject of a "60 Minutes" television broadcast on the U.S. CBS network on 21 Feb. 82. Journalists were especially fond of Perry inasmuch as he was unshackled by the secrecy normally shrouding the topic. And although the consensus of journalists was that he probably didn't learn much about Soviet space hardware that wasn't already known, he was in fact the only source willing to talk. Perry was said to have commanded notable respect mainly on the basis of his extraordinary deductive ability and his uncanny talent for extracting the most information from minimal instrumentation.

A group under Perry called the "Kettering Group" numbering about 10 around the world will continue the activities.

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TAPR Opens Office In Tucson

Tucson Amateur Packet Radio (TAPR) President Lyle Johnson, WA7GXD, sends the following:

Tucson Amateur Packet Radio (TAPR), an international Amateur packet radio research and development group based in Tucson, Arizona, is proud to announce the opening of its office, effective Monday, 20 August 1984!

The office address is:
Tucson Amateur Packet Radio
1016 East Pennsylvania Avenue
Suite 302
Tucson, AZ 85714

The mailing address remains:
Tucson Amateur Packet Radio
P.O. Box 22888
Tucson, AZ 85734-2888

The telephone number is:
(602) 746-1166

The office hours are:
9:00 AM - 5:30 PM
(Mountain Standard Time)
Monday - Friday

The gentle voice at the TAPR end of the line belongs to Karen Makus. Karen is a non-technical person, so please don't ask her how to write a terminal program for your packet station! However, in her role as Office Manager, she will do everything she can to expedite servicing your information requests, providing spare parts support for your TAPR TNC, filling orders and the like.

Technical questions will be routed to volunteer staff for answering, so please mail such questions to the TAPR PO Box.

It is our goal to provide 48 hour (or faster) turnaround on all standard transactions (memberships, renewals, TNC and parts requests, general information needs, etc.) and faster service on non-standard ones.

We at TAPR wish to thank you for your continued support, and look forward to being of greater service to you through our new facility.

The AMSAT booth at the ARRL National Convention, New York, 21 July 84. (l-r) K2UBC, WA2LJM, KA1M

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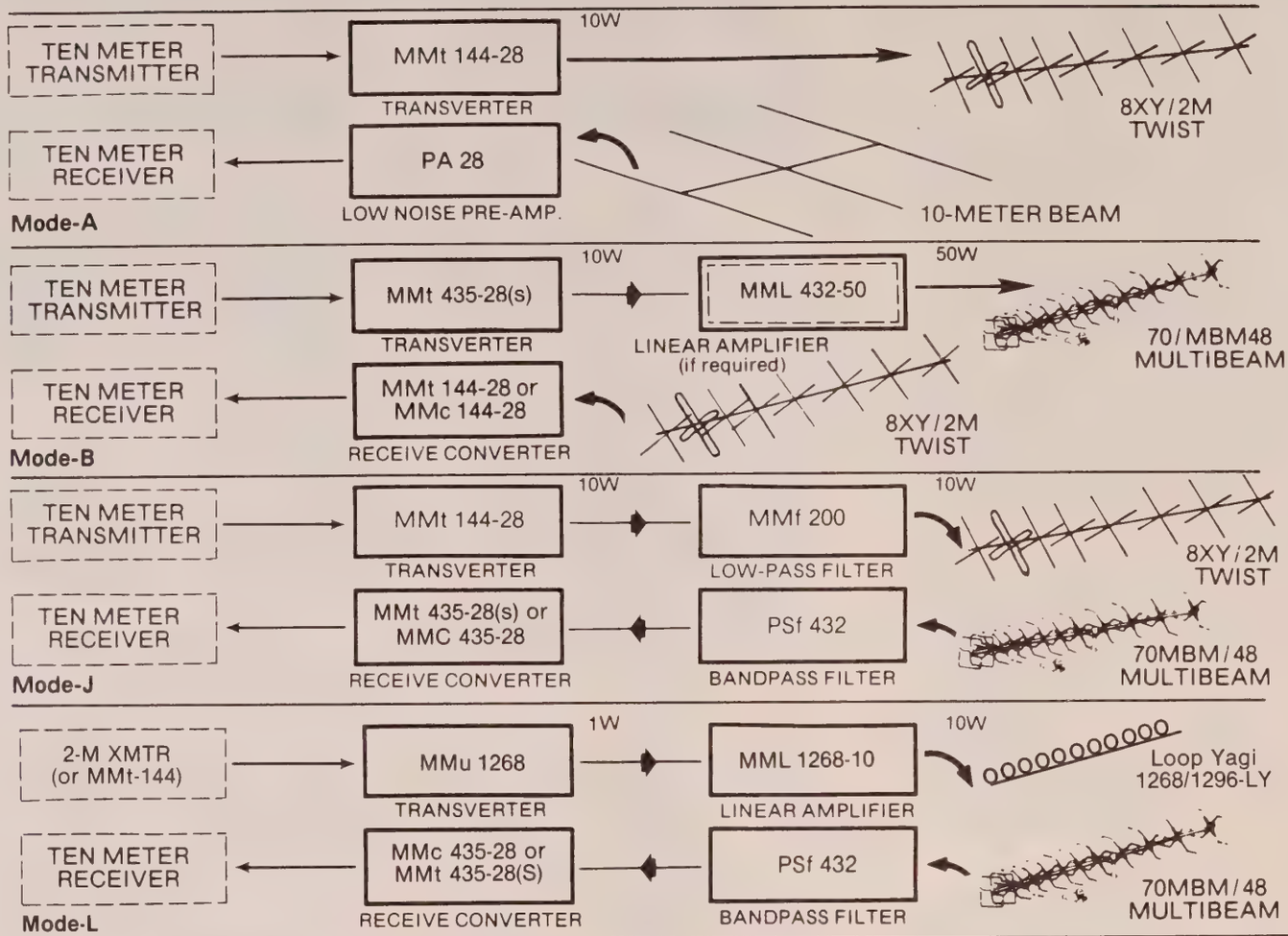

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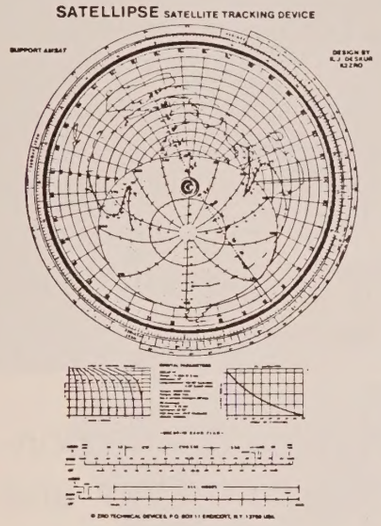

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The New Yaesu FT-726R Tribander is the world's first multiband, multimode Amateur transceiver capable of full duplex operation. Whether you're interested in OSCAR, moonbounce, or terrestrial repeaters, you owe yourself a look at this one-of-a-kind technological wonder!

Multiband Capability

Factory equipped for 2 meter operation, the FT-726R is a three-band unit capable of operation on 10 meters, 6 meters, and/or two segments of the 70 cm band (430-440 or 440-450 MHz), using optional modules. The appropriate repeater shift is automatically programmed for each module. Other bands pending.

Advanced Microprocessor Control

Powered by an 8-bit Central Processing Unit, the ten-channel memory of the FT-726R stores both frequency and mode, with pushbutton transfer capability to either of two VFO registers. The synthesized VFO tunes in 20 Hz steps on SSB/CW, with selectable steps on FM. Scanning of the band or memories is provided.

Full Duplex Option

The optional SU-726 module provides a second, parallel IF strip, thereby allowing full duplex crossband satellite work. Either the transmit or receive frequency may be varied during transmission, for quick zero-beat on another station or for tracking Doppler shift.

High Performance Features

Borrowing heavily from Yaesu's HF transceiver experience, the FT-726R comes equipped with a speech processor, variable receiver bandwidth, IF shift, all-mode squelch, receiver audio tone control, and an IF noise blanker. When the optional XF-455MC CW filter is installed, CW Wide/Narrow selection is provided. Convenient rear panel connections allow quick interface to your station audio, linear amplifier, and control lines.

Leading the way into the space age of Ham communications, Yaesu's FT-726R is the first VHF/UHF base station built around modern-day requirements. If you're tired of piecing together converters, transmitter strips, and relays, ask your Authorized Yaesu Dealer for a demonstration of the exciting new FT-726R, the rig that will expand your DX horizons!

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TR-9130

All mode (FM/SSB/CW) 25 watts, plus...!!!

The TR-9130 is a powerful, yet compact, 25 watt FM/USB/LSB/CW transceiver. Available with a 16-key autopatch UP/DOWN microphone (MC-46), or a basic UP/DOWN microphone.

TR-9130 FEATURES:

- 25 Watts RF output on all modes, (FM/SSB/CW).
- FM/USB/LSB/CW all mode. Selectable tuning steps of 100-Hz, 1-kHz, 5-kHz, 10-kHz.
- Six memories. On FM, memories 1-5 for simplex or ±600 kHz offset, using OFFSET switch, Memory 6 for non-standard offset. All six memories may be simplex, any mode.
- Memory scan.
- Internal battery memory back-up, using 9 V Ni-Cd battery, (not KENWOOD supplied). Memories are retained approx. 24 hours, adequate for the typical move from base to mobile. External back-up terminal on the rear.
- Automatic band scan.
- Dual digital VFO's.
- Transmit frequency tuning for OSCAR operations.
- Squelch circuit for FM/SSB/CW.
- Repeater reverse switch.
- Tone switch.
- CW semi break-in; sidetone.
- Compact size and lightweight.
- Covers 143.9 to 148.9999 MHz.
- High performance noise blanker.
- HI/LOW power switch. 25 or 5 watts on FM or CW.
- RF gain control. • RIT circuit.

Optional accessories:

- KPS-7A AC power supply.
- PS-20 AC power supply (TR-9500 only).
- BO-9A system base with memory back-up supply.
- SP-120 external speaker.
- TK-1 AC adapter for memory back-up.

TR-9500

70 CM SSB/CW/FM transceiver

- Covers 430-440 MHz, in steps of 100-Hz, 1-kHz, 5-kHz, 25-kHz or 1-MHz.
- CW-FM Hi—10 W, Low—1 W. SSB 10 W.
- Automatic band/memory scan. Search of selected 10-kHz segments on SSB/CW.
- 6 memory channels.

TS-780

All mode "Dual-Bander" ...2-m & 70-cm all mode, dual digital VFO's, 10 memories, scan, IF shift...

TS-780 FEATURES:

- USB, LSB, CW, FM all mode, covering the 2-m band (144.000-148.000 MHz) and the middle 70-cm band (430.000-440.000 MHz). UP/DOWN band switch.
- Dual digital VFO's with normal/tight drag switch. VFO steps in 20-Hz, 200-Hz, 5-kHz, or 12.5-kHz, plus "FM CH" channelized tuning. Split (cross) frequency operation possible. F. LOCK switch provided.
- 10 memories include band and frequency data, backed up by internal batteries (not supplied). Battery life exceeds one year. Memories 9 and 10 for priority instant recall.
- Band scan, with selectable 0.5, 1, 3, 5, and 10-MHz scan bandwidth.
- Memory scan selectable for all memories, or 2-m or 70-cm only.
- IF shift circuit rejects adjacent interference.
- High sensitivity and wide dynamic range.
- 7 digit fluorescent tube digital display.
- 10 watt RF output.
- 2-m ±600-kHz TX offset switch with reverse switch.
- Tone switch for optional TU-4C programmable two-frequency CTCSS encoder unit.
- VOX and semi break-in CW built-in.
- FM center-tune meter.
- Noise blanker for SSB, CW.

TS-780 accessories:

- **TU-4C** programmable two-frequency CTCSS encoder.
- **MC-42S** 500 Ω UP/DOWN hand microphone.
- **MC-48** 16-button Autopatch UP/DOWN microphone.
- **MC-60A** deluxe desk top microphone.
- **MC-80** desk top UP/DOWN microphone.
- **TK-1** AC adaptor for memory back-up.

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